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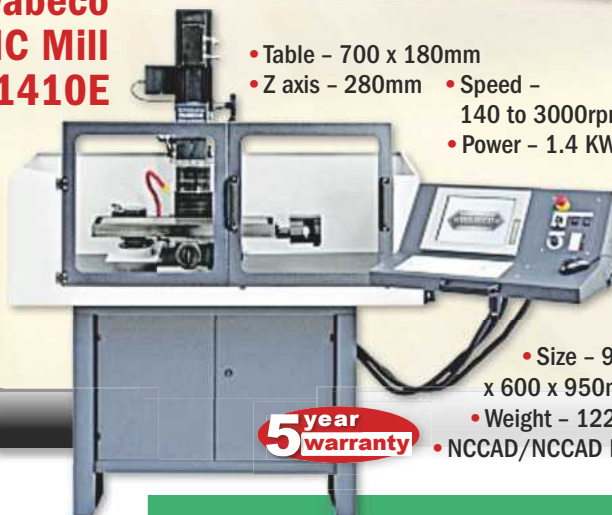


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On the Editor's Bench

Welcome to 2015

As the

accompanying picture by

M. Jacques Morel shows, there were plenty of seasonal good wishes

exchanged on the Model Engineer web forums. It's

now a good time to reflect on plans for the next year. If you are like me, then the past year has probably seen the list of projects grow, rather than shrink.

Certainly taking up the reins of *MEW* has been a double edged sword for me, with more reason to be active in the workshop, but probably less time than ever to actually do things! In 2015, rather than trying to work through all my unfinished projects - and failing to finish any, I think I'll focus on choosing a few 'headline' projects and try and polish them off. Naturally one will be the Super Adept lathe, but I will also aim to complete at least one engineering model and a couple of electronic based projects. I think I will also try and do more 'short, sharp' projects. Away from specific projects, I think my work could benefit from more effort spent on jigs and fixtures, as well as more attention to tool and cutter sharpening. So, what are you planning for the coming year?



New Authors

I'd like to thank the readers who responded to my call for new authors in the last issue. I have already received a number of interesting offers of articles on topics which will help keep up the breadth and variety of content *MEW* is known for. I should add that this isn't a purge of established authors - the magazine needs a mixture of

experienced writers and fresh new ideas. As always, email neil.wyatt@mytimemedia.com letting me know of any ideas you have for an article, or if there is anything you would particularly like to see covered.

Model Engineer Exhibition

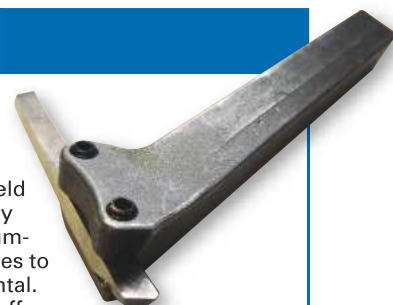
I greatly enjoyed the Model Engineer Exhibition at Sandown, and was able to meet many readers and contributors, as well as many well-known faces in the world of model engineering. Perhaps this is one of the best parts of attending the show; you don't just get to see possibly the finest display of model engineering anywhere in the world, but you can meet the people behind those remarkable achievements and just how approachable and ready to share their thoughts and ideas they are.

Meet the Makers

At Sandown I was struck by the constant stream of visitors to the 'Makers Area'. It was not a case of sceptical old engineers coming to see what the youngsters were doing with plastic and microchips - everywhere there was earnest and inspiring discussion of the possibilities offered by fusing new technologies with traditional skills. I commented to one chap exhibiting various embedded microcontroller projects that the real revolution will come when today's makers become 'empty nesters' - what sort of projects will they come up with when they find they have some serious workshop time and resources? Some clues to the answer come from the SMEE Digital Workshop; with their encouragement I have ordered some laser-cut parts for a tiny Piccolo 3-axis CNC machine. More news on this cute beginner's project in a future issue.

WIMBERLEY TOOL HOLDER

Many readers and users of the Model Engineer forum will be familiar with tangential tooling and the advantages it offers. My interest was piqued by a few folk mentioning a very different tool which they also held in high regard. I've been in touch with David Wimberley who produces his own distinctive toolholder for medium-sized lathes. Like a tangential holder it has special angles to simplify grinding, but it holds the toolbit nearly horizontal. Although more faces have to be ground, it potentially offers more tool shapes than a tangential holder. As the relief on all ground faces is both the same and over a small area, it is not greatly more involved to sharpen the tool. Because the tool is really for lathes of 4-inch centre height and above, I'm having to make a special adaptor for my quick change toolpost, but I will try out the tool over the next few weeks and report back.



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Coming up...

in the March issue

WORKING FOR THE CLAMPDOWN

Brian Moseley describes the construction of a handy tilting 'mini vice'.

This ingenious design uses a double clamp beneath the workbench for extra flexibility.



PLUS *Inchanga* recounts the ups and downs of twenty years living with a far-Eastern milling machine, Mike Haughton describes secure carriage locks for the Myford Super 7 & Chester Craftsman lathes, John Ashton fits a Quick Change Toolpost to his Toolco 1130gv lathe and much more.

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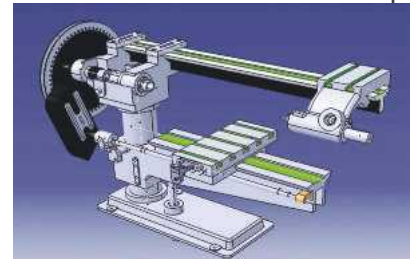
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to download a comprehensive document with further details,

including dimensioned plans, of David Urwick's unconventional Metal Master machining centre, featured in this issue.



FREE PLAN: A Spindle Moulder

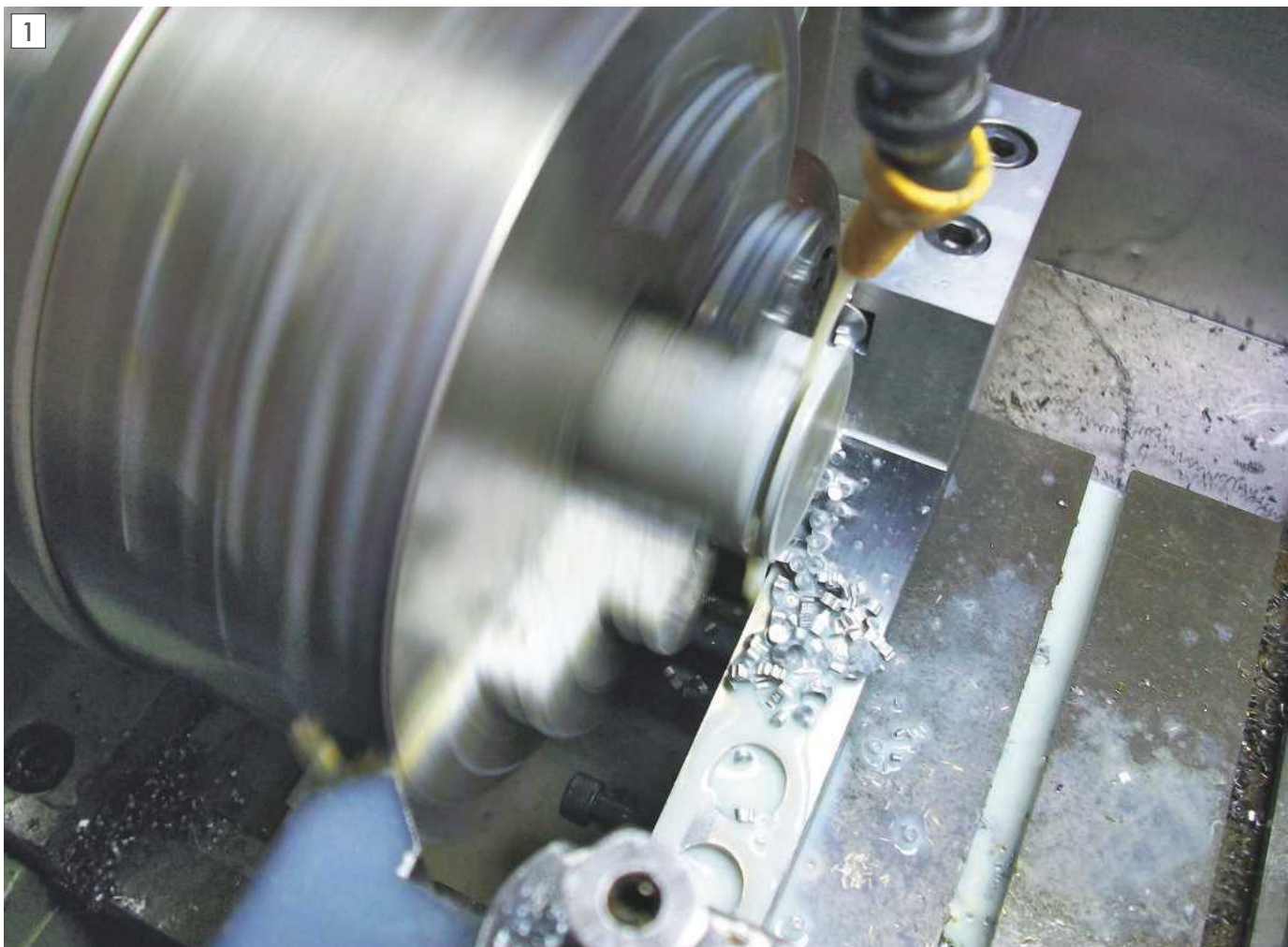
A request from a forum member led to a digital reprint of Norman A. Ough's 1954 Model Engineer article describing and detailing a miniature spindle moulder. In effect, this is a dedicated machine to do the same task as a table mounted router. A spindle below a work table has shaped cutters pointing upwards for profiling wood and the softer metals.

News from the 2014 Model Engineer Exhibition

See this report posted live while the exhibition was taking place. The report features photos of models, tools and all other aspects of the event.

Some of the other live topics on the forum include:

- > Side Shields for Safety Glasses – what's the most cost effective way to protect your eyesight in the workshop?
- > The Warco WM250 Family – users of this popular lathe compare notes and ideas.
- > What did you do today (2015)? – A new thread kicks off to share your workshop highlights of 2014, and your plans for 2015.



Parting off in the metal lathe



What are the forces that make parting off such a chancy business? Rather than just theorising, Reg Merryweather actually did some experiments to find out.

Let us look at the problems when parting off. The blade digs in and breaks or chatters or screeches like a harpie which you will agree is very off putting, even when the top slide gibs are tightened right up and as much play as possible is removed from the toolpost area.

Rear toolpost parting off is much better, it seems, than the normal front mounted method as it is usually more rigidly mounted, however the blade can still grab as the cutting forces applied tend to lift the saddle assembly off the bed 'V' ways (as some well-known 'gurus' are wont to tell us). The same sort of reasoning would apply to the front or rear tool system

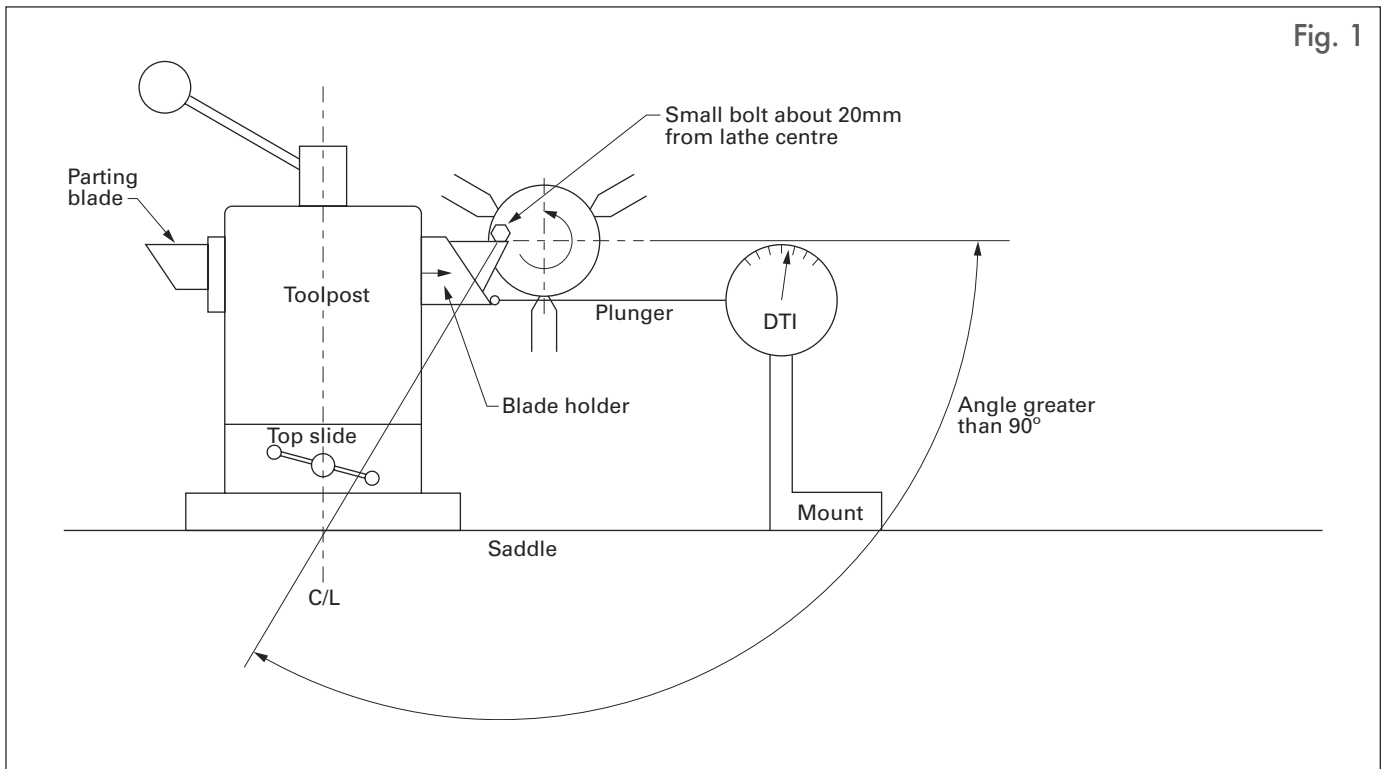
which would also tend to lift the tool away from the bedways.

I decided to find out exactly what happens using the normal arrangement on the front toolpost. I drilled a small hole (4.9mm) in the end of a short piece of 45mm round stock and as close to the edge as possible and bashed (technical term meaning force fitted) a short length of steel rod about 5mm diameter into the hole. This was chucked in the lathe. The parting tool was set up as you would for use and the tool wound in on the cross slide until the parting blade was just under the protruding piece of rod and stopping the lathe from turning. Referring to **fig. 1** it

will be clear as mud. I also set up a DTI to measure any movement of the tool holder.

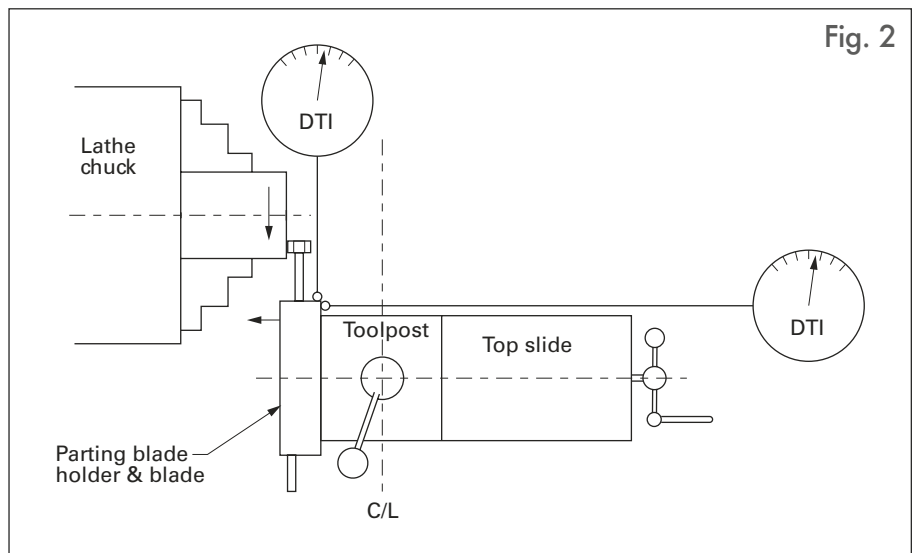
Disengaging the lathe drive train and switching the machine off from the power, I found that by using only moderate hand pressure to turn the lathe chuck in the direction of rotation that the whole toolpost assembly leant towards the lathe centre by .019 inch, it could be forced further without much more effort. I stopped and made sure yet again that the entire toolpost assembly was as tight as possible. It was so I concluded that any sort of resistance to turning would cause the blade to move into the work taking an extra heavy cut and causing even greater resistance to turning.

Fig. 1



I now set up the DTI to read how much the tool holder moved sideways (fig. 2), Referring to the next drawing for the set up I used, I found that the tool holder moved towards the headstock by .014 inch, again this was using moderate pressure by hand to turn the lathe chuck in the direction of rotation.

Fig. 2



Rear toolpost parting off is much better, it seems, than the normal front mounted method as it is usually more rigidly mounted.

You will see from figs 1 and 3 that the toolpost moves both toward the lathe centre line and also towards the headstock at the same time. What is happening to our parting blade that we ever so carefully set up for the job that we were about to part from the bar? The poor blade is under pressure, so what happens? The tip of the blade is forced further into the work as the resistance to turning is felt, this causes the blade to cut deeper and this results in even more resistance until something gives, usually the blade (and your temper) and results in your job being ruined and your bar fridge taking a hit.

Now, if that is not enough problems, at the same time the tool holder is moving towards the headstock causing a side loading on the parting blade resulting in stress as shown above. These two forces appear to strain the blade in such a way as to cause it to fracture in at least three bits (fig. 4).

Fig. 3

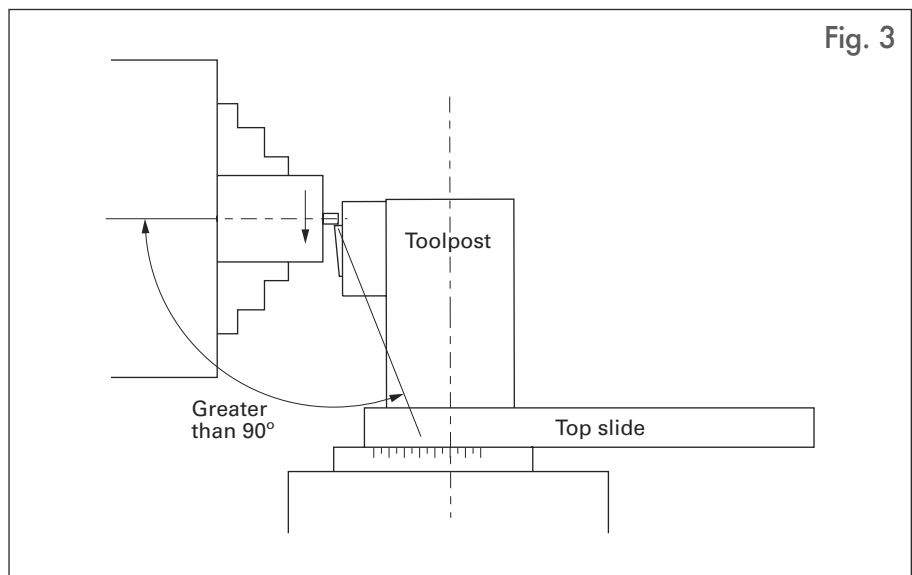
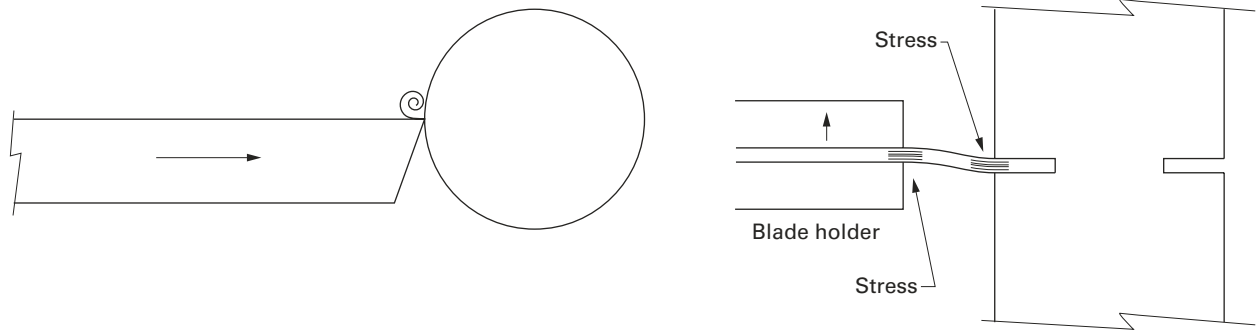


Fig. 4



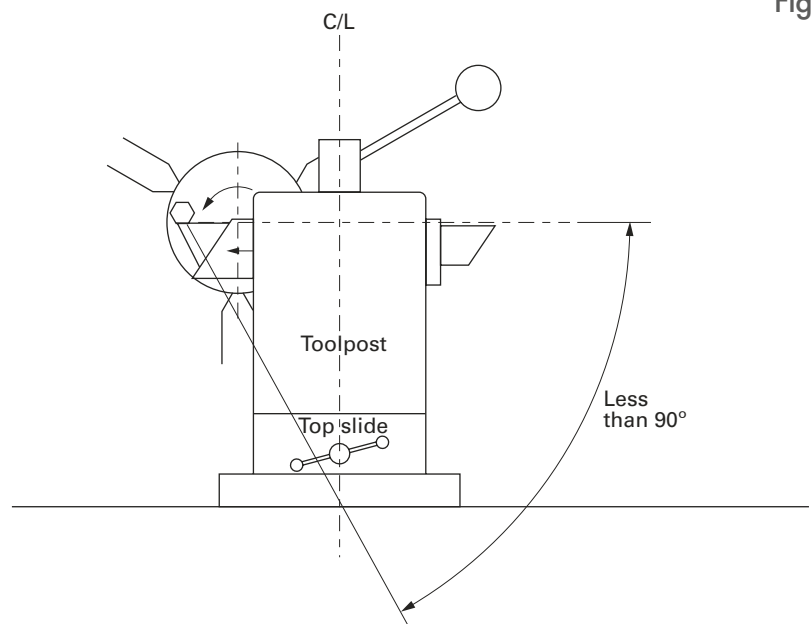
What are we going to do about it? We have to reduce the angle between the toolpost centre line and the tool cutting edge and the headstock centre to less than a right angle. This will cause the cutting face of the tool to move away from the work when extra resistance to turning is felt allowing, it is hoped, for the blade to clear its self.

Going back to our original set up, if we now put our blade protrusion to the operator side of the toolpost (fig. 5) and turn by hand once more in the direction of rotation and read the DTI we find that the tool holder has moved the opposite way to the previous reading as the angle is less than a right angle.

It is just too easy is it not? All we have to do is design and make a tool holder with a pressure angle of less than a right angle. See **photos 1, 2 and 3**. This is the tool I made cutting a washer of 45mm diameter at 280rpm and a feed rate of .00084 inch per rev. ■

Editor's Note: Reg has offered to prepare a dimensioned drawing of his toolholder for a future issue.

Fig. 5



Parting off a washer with Reg's holder.



The construction of Reg's toolholder is clear from this view.

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Fitting, Repairing and Using an Adjustable High-speed Threading Unit



Andrew Johnston describes a useful device rarely seen in hobby workshops, but occasionally available second hand.

A useful feature of a centre lathe is the ability to screw cut threads using a gear train between the spindle and leadscrew to move the carriage one pitch of the thread per revolution of the spindle. The pitch of the leadscrew and the ratio of the gear train between spindle and leadscrew determine the pitch of the thread being cut. The geometry of the thread is determined solely by the shape of the cutting tool.

In operation there are two half nuts that are engaged around the leadscrew when cutting commences, and are disengaged at the end of the cut. The carriage is then wound back to the start, the depth of cut adjusted, and a new cut commenced. Screwcutting lathes normally have a thread dial on the side of the carriage. This consists of a dial with numbers on the periphery, connected to a gear that meshes with the leadscrew. For a given thread pitch, charts indicate at which numbers the half nuts should be engaged. This only applies to a lathe with an imperial leadscrew cutting imperial threads, or a lathe with a metric leadscrew cutting metric threads. When cutting metric threads on an imperial lathe, or imperial threads on a metric lathe, the half-nuts need to be kept engaged for the whole screwcutting process.

One of the problems with screwcutting is finishing the cut in the same place at each pass. On an external thread the normal approach is to have a runout, a section where the diameter is less than the minimum thread diameter so that once the tool runs into it doesn't cut. This is reliant on the operator opening the half nuts at the correct time. Using runouts becomes fraught when cutting internal threads, as it is difficult to see what is going on. The



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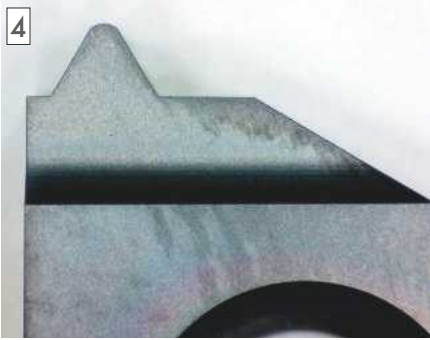
consequences of not opening the half nuts at the correct time could be a crash, resulting in damaged tooling and work.

The introduction of carbide inserts for turning tools allowed much higher speeds to be used, enhancing productivity. Many inserts need to be run at high speeds to get the best finish. In due course carbide inserts became available for single point threading, and these too benefit from running at higher speeds. This exacerbates the problem of disengaging the half-nuts at the correct time.

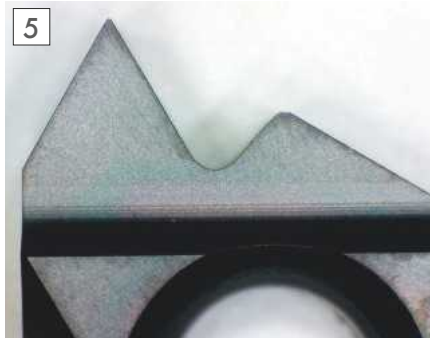
Before looking at a solution to the problem of high speed threading a few words about carbide threading inserts might be useful. These normally come as triangular inserts, with three threading edges per insert. Internal and external threading toolholders, with inserts are shown in **photo 1**. The inserts come in external and internal variants, and in two forms, full and partial profile. Many readers will be aware that different thread forms have different angles between the flanks of the thread. For Whitworth threads the

angle is 55 degrees, but for the US Unified series, and metric, the angle is 60 degrees. What may be less well known is that the thread forms are not usually a sharp V shape but have shaped roots and crests. The roots and crests are defined in the standard for a particular thread form. For a Whitworth thread both the crest and root are an arc with a radius equal to $0.137P$, where P is the thread pitch. A full profile external Whitworth 8tpi insert is shown in **photo 2**, showing the radius for root and crest. The Unified thread ideally has flat crests and roots, although in both cases rounding is allowed. An insert for cutting an external Unified 8tpi thread is shown in **photo 3**; the root is rounded, but the crest is approximately flat. The theoretical metric thread also has flat crests and roots, although the root is normally rounded for better fatigue resistance. An insert for an external ISO metric thread of 2mm pitch is shown in **photo 4**, showing a rounded root but a flat crest.

A full profile insert will cut one thread pitch only and correctly forms both the



Insert ISO Metric 2mm.



Insert ISO Partial Profile.



Inserts Internal and External ISO Metric.

crest and root. A partial profile insert will cut a range of pitches, but for an external thread does not form the crest, and the shape of the root is a compromise. A partial profile insert for ISO metric threads is shown in **photo 5**. This insert will cut pitches from 0.5 to 3 millimetres. Note that the root radius is too small for the larger pitches, as it needs to be correct for a thread of 0.5mm pitch. An insert for cutting an internal thread is a mirror image of the external in terms of clearances. What may not be quite so obvious is that the thread depth, and root and crest shapes may be different, as specified by the thread standard. An internal and external insert for ISO metric 2mm pitch are shown in **photo 6**, internal insert at the bottom. The different thread depths and root radii can be clearly seen.

Ainjest High Speed Threading Unit

For industrial lathes the problem of high speed threading commensurate with the capabilities of carbide inserts was solved with the addition of an Ainjest high speed threading unit. The units were made by Sanderson & Costin, of Newbury, who no longer appear to be in business. The unit is intended to sit on the side of the carriage and contains its own set of half-nuts that engage with the leadscrew. Another feature is a lever underneath the unit that can be used to disengage the half-nuts via a trip mechanism. The disengagement is tripped by a settable block on a trip bar that runs the length of the lathe bed. A variant of the basic Ainjest unit is required for each type of lathe to which it can be fitted, as the details of mounting and the positioning of

the leadscrew will be different. My lathe is a Harrison M300, and is imperial. A different, and rather more complex, Ainjest unit is required for metric lathes. A picture of the Ainjest unit fitted to my lathe is shown in **photo 7**, with the trip bar labelled.

Fitting and Using the Ainjest Unit

Given that the Ainjest unit I obtained was intended for my lathe, fitting it was simply a case of fitting bolts into the carriage as required. Tapped holes in the carriage were already present, presumably from manufacture. The unit replaces the normal thread dial indicator, which becomes redundant. On my lathe the lever with the red knob (spindle power - down for forward, up for reverse) that normally sits on the right hand side of the carriage simply moves to the right hand side of the Ainjest unit. The trip bar that came with the unit was intended for a 25 inch between centres version, whereas my lathe is 40 inches between centres. I simply replaced it with a longer length of standard $\frac{3}{4}$ by $\frac{1}{4}$ inch cold drawn bar. Machined pads and tapped holes for fixing the trip bar were already present on the lathe.

Using the unit is simple. The settable block on the trip bar is moved to the appropriate place and locked with a set screw. The trip lever underneath the unit is moved from its safe position so that it can catch the block when the carriage is at the correct place. The round silver knob at the top of the unit is moved from position '0', which is the safe position and will not allow engagement of the half-nuts, to one of three operating positions. Position '1' is for fractional quarter threads, eg, $3\frac{1}{4}$ tpi,

position '2' is for fractional half tpi threads, eg, $4\frac{1}{2}$ tpi, and position '4' is for whole integer tpi. The screwcutting gearbox on the lathe is set to cut the required thread pitch as normal. The half-nuts in the unit are then engaged with the leadscrew at the correct point, as allowed by slots in a disc on the silver knob, and using the black operating handle in a similar way to engaging the half-nuts during normal screwcutting. At the end of the pass the unit trips and disengages the half-nuts. The thread is cut using as many passes as are required as for normal screwcutting.

Damage and a Repair Scheme

When first using the unit I made a fundamental error, and damaged the main casting on the Ainjest unit. Having cut a trial thread I decided to clean up the diameter of the workpiece before cutting another thread. A simple procedure, swing the toolholder to a normal turning tool and use the power feed to move the carriage. My mistake was that I had not moved the trip lever to the safe position. As the carriage moved under power feed the trip lever engaged the trip block but since the threading unit was not engaged the trip mechanism didn't trip, but just presented an increasing load on the bracket holding the trip lever. The lathe started to sound a bit laboured and I knocked the power off, but not early enough. The trip lever sits on a cantilever bracket with two screws into the unit main casting. This had been subject to a large twisting force which broke the casting around one of the screw holes, see **photo 8**. I took the unit off the lathe, and it sat on the bench for about a year while I considered possible repair



Ainjest Unit Fitted.



Damage to Main Casting.

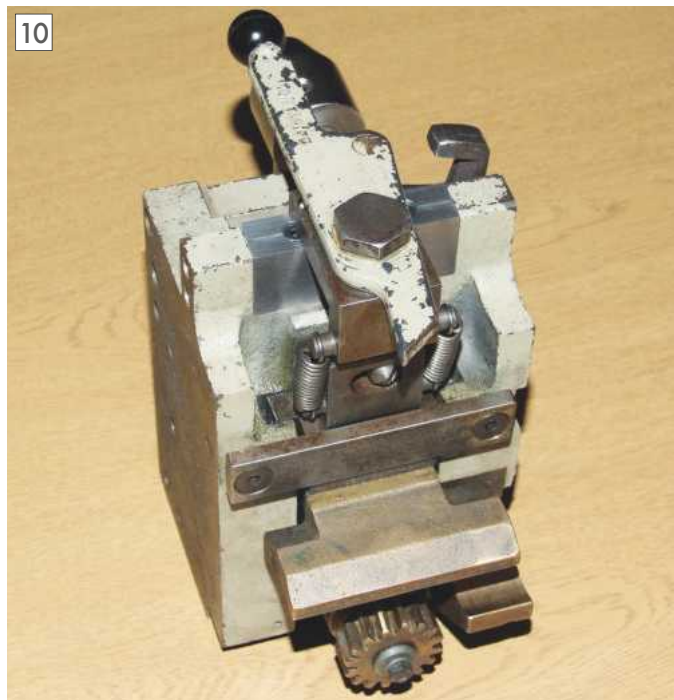


New Part Ready for Assembly.

schemes. The unit mirrors changes in industry during the second half of the 20th century, in that the vertical holes are threaded M5 but the horizontal hole is threaded $\frac{1}{16}$ BSW. Eventually I decided that the best plan was to completely replace the area of the casting that contained the M5 and $\frac{1}{16}$ BSW threads. Measurement of the unit and modelling in CAD, using imperial units, showed that I could fit a block and have room for fixing bolts. The partially disassembled unit, and the new block (bottom left) are shown in **photo 9**. The block (machined from gauge plate) is fitted to the main casting with two vertical M4 bolts and two M4 bolts in from each side. In photo 9 it can be seen that the casting has the central portion milled away ready for the new block. I didn't completely dismantle the unit when machining the casting, but paper was taped all around the mechanism, and to the mill table to prevent ingress of the cast iron swarf and dust. **Photograph 10** shows the repaired and re-assembled unit. It would have been better if I hadn't broken the darn thing in the first place, but at least the repair is reasonably neat.

Examples of Using the Unit

In **photo 11** are some parts which have screw threads cut using the Ainjest unit. The fine threads are 50mm diameter, 26tpi Whitworth form threads. The diameter is metric because I design in metric, but the threads are Whitworth because my lathe is imperial. These parts form a one-off experimental jig, so the actual thread doesn't matter. However, a close fit is required, as when screwed together the enclosed chamber is subject to water pressure at 250psi. The internal thread is shown in close-up in **photo 12**. The thread is within one pitch of the bottom of the part. To set the trip for the internal thread proceed as follows. The trip block is roughly set and the half-nuts engaged, the unit moves and then trips, with the tool well clear of the work. Once it is ascertained that



Unit Reassembled.

the tool will not crash into the work, the unit can be engaged and tripped again, but this time with the tool inside the work. The distance from tool to work can then be fine tuned by using the compound slide. I used a clearance of 10 thou.

Another example of a screwcut thread using the Ainjest unit is shown in **photo 13**. This is an embryo hob, made from silver steel, for free hobbing a 4 inch diameter 22 tooth worm wheel. I find that I get a better finish on silver steel at higher speeds, hence the use of the Ainjest unit. The thread is another odd one; the shank diameter is 25mm, but the thread is 20tpi Whitworth, so that it will fit a Clarkson milling chuck collet.

The Ainjest manual states that threads can be cut at up to 3000rpm. However, at these speeds considerable loads would be exerted on the half-nuts, and the unit, as they accelerate the carriage. In practise I

have found that above about 800rpm, for fine pitch threads, it is difficult to get consistent engagement of the half-nuts. For coarser pitch threads a slower speed is advisable. On the parts shown in photo 11 the coarse thread on the left, $\frac{3}{4}$ BSP, was cut using the Ainjest unit at 500rpm.

Cutting Metric Threads

My lathe is imperial, and while it has metric pitches incorporated into the gearbox the half-nuts need to be kept engaged when cutting a metric thread. Clearly this is not possible when using the Ainjest unit, as it automatically disengages the half-nuts at the end of a cut. There is a piece of equipment, called a Metradial, that can be used in conjunction with an imperial Ainjest unit to cut metric threads. Essentially this is a thread dial indicator. There is a company in the UK



Parts with Screwcut Threads.



Detail of Internal Thread.



Embryo Hob with Screwcut Thread.

that purports to sell the Metradial, but they do not seem to be active. The Metradial is intended for use on imperial lathes that have an exact conversion to metric, i.e. there is a 127 tooth gear in the gear train from spindle to leadscrew. If the metric conversion is not exact then the Metradial will still function but there will be a cumulative angular error at each successive pass. This can be ameliorated by either cutting the thread in a minimum number of passes, or advancing the compound slide by 0.0035 times the thread pitch (in millimetres) at each pass. My lathe falls into the latter category, as it incorporates the ratio 288/7315 in the screwcutting gearbox.

In essence the problem of cutting metric threads on an imperial lathe is one of getting the spindle and leadscrew back into the alignment they were originally in, for subsequent cuts. This is essentially a problem in integer arithmetic. My leadscrew is 4tpi, so the pitch is $\frac{1}{4}$ inch, or 6.35mm.

Suppose we are cutting a 0.45mm pitch thread. From the start if we turn the spindle by whole turns then the spindle and leadscrew will be in the same orientation with respect to each other when:

$$6.35m = 0.45n$$

where both m and n are integers. Multiplying by 100 we get:
 $635m = 45n$

And dividing by 5 gives:
 $127m = 9n$

Now 127 is a prime number so the equality cannot be further factorised. So $m=9$ and $n=127$. Going back to the pitches involved we have:
 $6.35 \times 9 = 57.15$ and $0.45 \times 127 = 57.15$

Extending to other metric pitches we see by examination that the metric pitch multiplied by 127 gives a number that is

an integer multiple of 6.35. However, these numbers, like 57.15, are not convenient. Another possibility is to return the spindle, leadscrew and carriage to the same position at the start of the thread for each pass. The spindle and leadscrew are geared together, so returning the spindle to its starting point will suffice. Resetting the position of the carriage is simple using a bedstop. Resetting the spindle is more involved. My solution involves fitting a rotary encoder to the spindle and counting the number of revolutions while doing a cut. If the lathe is then reversed and the count taken back to zero, the spindle, and leadscrew, should be in the original alignment. In practice it would be prudent to use an encoder disk with many lines, say 360, per revolution. It would also be sensible to go beyond '0' before coming back, in the same way as when accounting for backlash. The setup will get built when I have a pressing need to cut metric threads using the Ainjest unit. ■

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Heat Treating

O1 & W1 Tool Steels

Part 2



Richard Rex has discovered that understanding the science behind steel leads to better results in the workshop.

Hardening carbon steels

Roughly speaking, the hardening process today is only a refinement of what I learned back at the forge: heat then quench. The back story is a little more complicated. First, the metal must be in the all-austenite state, meaning above the UCT. Second, you need to know that quenching forms an entirely new phase called **martensite**. Yes, another 'ite' word. There are at least eight in the steel literature; this article talks about only five. Martensite is responsible for tool steel's useful qualities.

Consider the case of an ordinary tool steel like O1 or W1. Looking at the Fe-C phase diagram, which depicts equilibrium conditions, we know that the metal must be entirely austenitic above the UCT, with all of its carbon (say 1%) dissolved into the wide-open spaces of FCC iron. Slow cooling through the UCT and below changes the composition to a mix of austenite and cementite. With further slow cooling below the LCT this is transformed again into cementite and pearlite. These processes take time.

But what if you don't allow the time? Suppose you **quench** it, cool it **very rapidly**, such as 2000°F (1100°C) per second. Unsurprisingly, this causes a violent, near-instantaneous transformation from austenite to something else entirely, namely **martensite**. Theoretically, martensite is all there should be in just-quenched steel at room temperature; in practice the martensite content may be as low as 60% or so, the remainder being austenite that didn't make the cut.

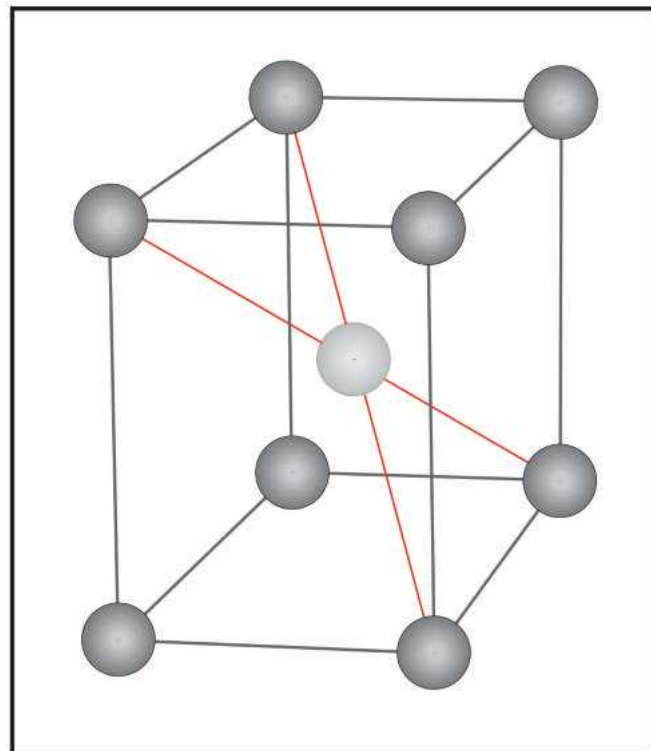
The change to martensite is dramatic indeed, like the shattering of safety glass. In a fraction of a second we have gone from the 14-atom FCC austenite to a stretched version of the 9-atom BCC, yet without losing any carbon, thus preventing the formation of pearlite. The new 'martensitic structure' is called a Body Centered Tetragonal, BCT (fig. 6).

Martensite is indeed a phase, but it is highly unstable and therefore doesn't appear on the phase diagram. It is a very hard and brittle form of steel with a hardness close to 65 RC (Rockwell 'C' scale), about the same as high speed steel. Martensite comes with a lot of

Until a year or so ago all I knew about hardening carbon steels was summed up in the one-liner: 'Heat to cherry-red, then quench in water'. You then tempered the piece – reduced its brittleness – by heating it to a lower temperature and re-quenching. I learned that as a blacksmith's assistant (more accurately, gofer), and have applied it ever since making scrapers, chisels and – now and again – milling cutters such as D-bits and counterbores from O1 and W1 tool steels. Now and again says it all: I didn't make them regularly enough to be troubled by quality control. Some cutters would last forever, others died in a minute or two, oh well. That's how it stood until a couple of recent failures prompted a closer look. This article is the result. It focuses on the O1 and W1 alloys because they are inexpensive, easily machinable in the model shop, and available overnight in a huge range of flat and round sections (especially O1).

Fig. 6

The structure of martensite



This is how iron atoms are arranged in martensite. It is a stretched cube called a Body Centered Tetragonal, BCT. Like BCC it has a single atom at its center but its properties are quite different.

internal stress and strain which, as you've guessed, we can relieve to the desired degree by cooking at a low temperature – in other words, by tempering.

What does tempering actually do?

This is a question that gets evasive answers, if any, mainly because the metallurgy is very complex. At the practical level we know that tempering makes the workpiece a usable tool, trading its hardness/brittleness for toughness. Tempering is a slow process, taking an hour or more in the oven. The short version of the story is as follows. Tempering stabilizes the steel in three stages:

- 1) By forming in the martensite very small 'intermediate' carbides (relatives of cementite, but not quite the same), then;
- 2) By decomposing retained austenite into ferrite and intermediate carbides, and;
- 3) Finally, by replacing the intermediate carbides with their more stable counterpart, cementite, Fe_3C .

Now, back to the shop

Do you really need to know all that austenite, cementite, martensite stuff for practical heat treatment? No, but it helps to talk the talk when your project calls for additional background.

The rest of this article describes the heat treatment of two machinable steels, O1 and W1, in the reverse order – W1 first, because it's more convenient, less messy, and it doesn't create odors and smoke ('W' means water-hardening, 'O' oil-hardening). What's special about O1 and W1 is that they are inexpensive, readily available, and machinable with regular HSS cutters – go slow, shallow cuts. Think 15 thousandths, 10 or even 5 until you have the feel of it. (The photo at the end of this article shows a shop-made counterbore being machined from W1 in a special fixture that is used for both initial milling and edge grinding.)

How do you know one W1 from another?

If you started at the top, you already know that W1, a.k.a. drill rod ('silver steel' in the UK), comes in various grades, meaning different percentages of carbon from content. Suppliers will usually tell you only that their W1 is W1, end of story. Lacking definite specs, we have to assume that W1 is 1% carbon. (A close relative of W1 is 1095, with 0.95% carbon). For 1% carbon steel we know from the Fe-C phase diagram that its UCT will be approximately 1500°F (815°C), the **pre-quench** temperature. This is only a few degrees hotter than the magnetic transition point, 1418°F (770°C), and so can be predicted reliably with a magnet.

W1 chemistry

W1 is a water hardenable steel, in production for well over 100 years. Its 'case hardness' and malleable core makes it, even today, the steel of choice for the best kitchen knives. W1 is a very basic

alloy, usually with only two components other than carbon (in silver steel there is also around 0.35% chromium):

Table 2: Composition of W1 Steel	
Typical chemistry of W1	
Carbon	1%
Manganese	0.25%
Silicon	0.2%

If your W1 really does have a higher carbon content, say 1.2%, its UCT of 1650°F (900°C) will be way beyond the magnetic transition. All you can do in such a case is rely on the hot colour – 'bright cherry red' – or, better, use a temperature-sensitive crayon such as a Tempilstik. Super-accurate control of the pre-quench temperature is not often necessary in the model shop, but serious over-heating may cause permanent damage to the surfaces you've carefully machined (so buy a Tempilstik for pre-quench temperature if you plan to do a lot of heat treating).

Size of workpiece to be heat treated

The counterbores and other cutters I am thinking of would range from 1/8 to 3/4 inch diameter. There is nothing to stop you working with larger diameters, but bear in mind that you will need greater heating capacity – possibly beyond a regular propane torch.

A word on torches

Ideally you'll want to use a 'one-hand' torch, the piezo-electric sort that self-ignite and self-extinguish – press and hold a spring-loaded button to light, release to extinguish. You cannot be holding the workpiece at the same time as you turn on the gas, then light the torch with a flint striker. Even worse and potentially dangerous, you don't have time to turn off

the gas when the quenching temperature is reached. None of this applies, of course, to the lucky few with furnaces and precision pyrometers: no need for magnets in that kind of setup – just let the workpiece cook for the necessary time at the desired temperature, then quench it immediately.

A propane torch flame is approximately 3,600°F (1,980°C). In theory that could melt steel, but it won't. Even with a heat shield of firebrick, you'll be lucky to get a pea-size piece of it hotter than 2,000°F (1,100°C - orange to yellow). Oxy-acetylene burns at over 6,000°F (3,300°C), giving plenty of headroom for anything you might want to do, including welding (but it can also overheat a small workpiece in a matter of seconds). In between the two is MAP-Pro (3,700°F, 2,070°C). MAP-Pro is propylene, not to be confused with the hotter-burning MAPP gas, which has not been produced in the USA since 2008.

If yours is a non-igniting 'two-hand' torch you might want to have an assistant on hand for the minute or two it takes to bring a workpiece up to quenching temperature.

The heat treatment setup

The best place for heat treatment is outside the shop; fumes are less of an issue and, provided you have eye/face protection, water splashes from quenching are low-hazard. Most of us work inside, with a fume hood if we're fortunate, reasonable ventilation if not. If you are relying on 'heat colour' to judge temperature, the best conditions are a gloomy day or late afternoon, no direct sunlight.

A welding table with steel top makes an ideal workbench for heat treatment, but there is no need for anything special. Provided its surface is protected from heat with (say) an inverted oven tray, a wooden top bench will do equally well. I use a mini kiln constructed of firebricks to focus heat on the workpiece, the only way I know to heat evenly with a torch. **Even heating is a must in heat treating.**



A mini-kiln for heat treating.

The few minutes it takes to build a kiln will be repaid many times over. Highly recommended! There is nothing critical about the dimensions; inside measurements of the kiln in **photo 1** are 1 x 1½ x 2½ inches. The lid is loose fitting, with a small gap at the rear to control blowback. It is made of **soft firebrick** from a kiln supplies company such as Bailey (their catalog reference: K23). One 9 x 4½ x 2½ inch brick is all you'll need; simply cut it into ¾ inch thick sheets using any type of handsaw, but not one you care about. Stabilize the construction using sawn-off nails as dowel pins in ½ inch holes (use an old drill in a hand chuck, no need for power). The downside of this is cost; the bricks themselves are inexpensive, but shipping is not. Two alternatives: buy one from a local potter who does his/her own kiln work, or build a different design using the smallest conventional firebricks you can buy from a masonry supplier.

For small W1 tools you need only quart (litre) or two of water (or brine, see inset) in a disposable metal container such as a coffee can. This needs to be positioned so you can plunge the workpiece quickly down into it with the minimum of air cooling on the way. For most purposes water quenching works fine for W1, but many prefer brine because it creates a protective coating around the steel as it is quenched, enhancing hardness by reducing decarburization scale. Use a 10% solution of ordinary table salt in water (start with a piece of raw potato in plain water, then add salt until the potato rises to the surface). Another way to arrive at the same point is to add about 3 ounces of salt to each quart of water.

If you plan on using the 'magnetic transition' to judge the pre-quench temperature, you will need to clamp your magnet to a rigid stand so you can tap it frequently with the workpiece when heating. Practically any magnet will do the job (suggestion: ½ inch diameter rare earth magnets from Lee Valley sell for about \$1 apiece).

Wear wraparound safety glasses to protect against hot water splashes.

Tempering

The blacksmith I trained with would temper a quench-hardened tool by brightening its surface with a file, then reheating its shank until the oxidation colours travelled toward the business end. When the leading colour ('light straw', 450°F, 230°C) reached the tool tip, he re-quenched immediately to 'fix' the temper. This is **not recommended** for small precision cutters – we are not making pry bars here. The main problem with tempering small tools this way is that once the colours appear at the shank end they get to the tip so fast you are almost bound to overshoot – which means too soft an edge. Aside from unpredictable hardness, re-quenching can leave the tool in a fragile, stressed condition.

We will use an oven instead, no quenching. In contrast to the hit-or-miss method it takes no effort, and is 100% predictable. The tempering oven can be as basic as a second-hand toaster oven, but it does need fairly accurate temperature control. **Photograph 2** shows one demoted from kitchen use some years ago, but it



Use an old toaster oven for tempering.

works well for heat treating. Note the second wire rack to prevent small parts falling through, and the thermometer – a lot more reliable than the oven's hit or miss temperature control.

It also needs a tray to keep workpieces off the oven floor, ideally something like a cooling rack for baked goods – not a flat sheet of metal. Decide on the desired hardness of the finished tool, then choose a temperature from **Table 3**.

Instead of relying on the dial markings, use at least one oven thermometer (two, better), and allow 20 minutes or so for the temperature to stabilize. Allow the workpiece to remain in the oven for at least **1 hour** (more, say 2 hours, for ¾ inch diameter and up), then turn off the oven and allow it to cool to room temperature. Within reason you can speed up the cooling process by removing the workpiece from the oven after the tempering session and allowing it to air-cool on a kitchen-style rack (not an insulating material such as firebrick). Avoid thermal shock. There is no harm at all in leaving the workpiece in the oven for more than the specified time; you **cannot over-temper** it (but that doesn't apply to the pre-quench 'soak' time, which needs to be close to the book).

W1 heat treating procedure

First, make sure that the tempering oven is at the desired temperature (see *Tempering* above), because you will be transferring the workpiece to it immediately after heating and quenching – which takes only a few minutes.

Bearing in mind the need for even heating, the following assumes you are using a mini kiln to concentrate the torch flame. With the workpiece held in an old pair of pliers or (better) a custom clamp, place it in the kiln leaving a short length of its shank protruding. Starting at the shank end, heat it with the torch while watching for colour changes. Bearing in mind that a

Table 3		
Oven Temperature	Rockwell °C Scale Hardness	
300°F	150°C	64
400°F	205°C	61
500°F	260°C	59
600°F	315°C	55

½ inch rod will take a good minute or two to come up to temperature, don't confuse the red hot glow of the firebrick (almost immediate) with the temperature of the workpiece. If you have a magnet on hand, use it to calibrate your sense of colour-temperature; while the workpiece is heating, remove it periodically from the kiln, then tap it against the magnet. When magnetic attraction ceases (dark-to-cherry red region) the workpiece is almost at quench temperature. Noting the colour, aim for a **shade** hotter, then – important – hold that temperature for a **soak time** depending on workpiece diameter: from **1 minute** (¼ inch) to **2 minutes** (½ inch) to **5 minutes** (1 inch).

Because lighting conditions vary, and therefore one's perception of colour, you might want to calibrate using the magnet every time you heat treat. **Don't overheat!** As steel is heated beyond 1000°F (540°C - visible heat) its surface begins to shed carbon, and scaling (flaking) appears. This is 'decarburization', to be avoided to the extent possible (a decarburized surface has practically no hardness). Even with a propane torch you can damage any size workpiece by decarburization. If this turns out to be a real problem in your application, use an anti-scaling powder such as Rose Mill PBC. Start the heat treatment process in the usual way, then stop when the workpiece is at 500°F (260°C). Dip the workpiece into the powder (which will melt), then continue to heat and quench.

After the specified soak time, be sure the workpiece is evenly heated all the way round – take a very quick glance – then plunge it vertically into the water or brine with a **rapid up and down motion** to prevent the formation of air pockets that slow the quenching. Wipe off the workpiece, then transfer it **without delay** to the already-heated tempering oven. Here I'm quoting Dave Smucker (Tidewater Blacksmiths), who says that – like me – he used not to pay much attention to the 'without delay' part, but it is important. He points out that a quenched part is in a highly stressed state, and wants to relieve that stress by cracking. Speedy transfer to the tempering oven will avoid that issue, but, **before you temper** the steel check its **surface hardness** with a file: if you have done the heating and quenching right, the file will skate freely over the surface – dead hard. If the file bites at all, the steel is too soft for use as a tool. Be sure to check for even hardness all around the tool. Don't waste oven time on a soft tool.

If the tool is not evenly hardened you could try heat-treating it again, but first it needs to be **annealed**. The problem here, at least in theory, is that annealing takes an hour or more at 'orange red' (about 1600°F, 880°C), well above the UCT, followed by slow cooling. If you don't have a furnace, the best you can do is hold the annealing temperature for a few minutes, then allow air-cooling to room temperature. This won't be a perfect restoration of pre-quench chemistry, but it may be enough to get by without re-making the tool. Table 3 shows tempering temperature vs. average hardness values (R_c) of W1. W1 hardness as quenched is approximately R_c 67. These numbers are from *Heat Treatment, Selection and Application of Tool Steels* by William E. Bryson.

How hard should my cutter be?

Most of the cutters we use every day are high speed steel, HSS, typically M2 alloy with a hardness of R_c 65. The theoretical hardness of W1, as quenched, is R_c 67, but you **cannot** use it in that condition. Without tempering, it is dangerously brittle.

You may wish to do your own experiments on hardness (= cutting ability) vs. brittleness. Assuming you are making cutters such as countersinks or counterbores, start by tempering at 350°F, the usual choice for W1 (for an even harder tool, you could go as low as 300°F). Finish the tool by grinding or hand-honing with a diamond lap, then test it on the mill or drill **using coolant** to avoid 'drawing its temper' (softening) by over-heating, see *Grinding and using carbon steel cutters*, below. If cracking is an issue, reduce the hardness for the next try by raising the oven temperature a few degrees. In general, use the lowest tempering temperature that makes sense for your application. See **table 4**, though these numbers are fairly arbitrary, depending on manufacturers' preferences (and quality, which is all over the map – literally). The idea for this table came from *Machine Shop Trade Secrets* by James Harvey, an excellent reference for all machinists, not just those 'in the trade'.

Product	Rockwell °C Scale Hardness
Micro-grain carbide	79
High Speed Steel	65
Files	65
Case hardened dowel pins	59
Single edge razor blades	58
Wood chisels, plane blades	58
Hobby knife blades	56
Locking pliers	55
Hex wrenches, screwdrivers	50
Machinist's scales (rules)	49
Axes	45
Socket head cap screws	42
Wood scrapers	38

Why O1 instead of W1?

You will find O1 (in Europe, typically gauge plate) somewhat harder to machine than W1, its quenching medium isn't free, and its hardness as-quenched is a tad lower. So why use it at all? The answer is that O1 offers a good all-round compromise of material cost, machinability, toughness, wear resistance, and a wider range of available shapes and sizes. It depends what you want your cutters to do. If you are cutting just a few dozen holes in mild steel, W1 will do the job. For a longer-lasting tool, go with O1. Just bear in mind that careful heat treatment can be more important than your choice of one versus the other.

O1 chemistry

O1 is a 'higher' alloy than W1, meaning it has more components. Most suppliers agree that its carbon content is 0.9%. It contains four times more manganese than W1. This is a carbide-forming element which, like the other additional components, chromium and tungsten (and sometimes vanadium up to 0.3%), enhances toughness in the tempered steel.

Typical chemistry of O1	
Carbon	0.9%
Manganese	1.1%
Chromium	0.5%
Tungsten	0.5%

Quenching oil

If you were to believe the web gossip you would think O1 can be quenched with just about anything, from used motor oil to Canola. That might be OK for some applications, but in the model shop we need more control. The key factor is 'quench severity', a measure of how fast heat is removed from the steel. This is the H parameter: it depends on

oil **viscosity**, oil **chemistry** and **agitation** of the workpiece in the quench bath. The higher the H value, the harder the steel. In ballpark terms, water quenching is 5 to 8 times more severe than oil quenching (brine even more so – about 10 times).

Commercial quench oils have proprietary additives to achieve fast, uniform quenching with the minimum of side effects. Most are available only in bulk, 5 gallons or more. The smallest quantity you can buy of any dedicated quench oil is probably 1 gallon, from McMaster Carr, more than you'll need in decades of heat treatment. At the time of writing this was available in two 'speeds', 11 and 28 seconds, which define their performance as measured by the GM Quenchometer, an industry standard. For model shop applications the 11-second type is recommended. Good results can also be obtained using a generic mineral oil such as baby oil. Vegetable oils are too viscous (poor heat removal), and are not recommended.

O1 heat treating procedure

Aside from the quenching medium, there is very little difference between the O1 and W1 processes. Use the same numbers as W1 for pre-quench temperature and soak times, ditto for tempering. When quenching, be sure to move the workpiece **vigorously up and down** to promote even cooling. **Have caution**, unlike water quenching, oil quenching leaves the steel **dangerously hot**, even if you leave it in the oil bath a minute or more. **Table 6** shows Tempering temperature vs. average hardness values (R_c) of O1. O1 hardness as quenched is approximately R_c 66. These numbers are from *Heat Treatment, Selection and Application of Tool Steels* by William E. Bryson

Oven Temperature	Rockwell °C Scale Hardness	
300 °F	150 °C	63
400 °F	205 °C	60
500 °F	260 °C	57
600 °F	315 °C	54

Grinding and using O1 and W1 tools

The bottom line on the subject is this: if the cutting edge of an O1/W1 tool exhibits **any discoloration** in use or when being ground, its performance is compromised – terminally. It's that simple. Even a light straw colour indicates 450°F (230°C), way higher than tempering temperature, so the tool is now softened. In some cases it may be worth annealing and heat treating all over again, but it may better to machine a replacement tool from scratch.

Avoiding this problem in use is simply a matter of taking shallow cuts, at the same time keeping the tool cool with an appropriate supply of, yes, coolant.

Grinding is something else again. With even the lightest pressure on the wheel a tool can be scorched in a matter of milliseconds. This is why, back in the day when HSS (high speed steel) was a rarity, grinders were supplied with a water

trough for easy dunking. With a precision grinder over-heating can be completely avoided – fully machine the tool in its pre-hardened state, then grind only to dress the cutting edges. In short, do the absolute minimum of grinding, with barely detectable feeds, like 0.001 inch, between passes. Keep the temperature of the surface you're grinding below 150°F (65°C), which is as hot as you can touch without (much) discomfort. Water dip frequently if convenient, air cool if not.

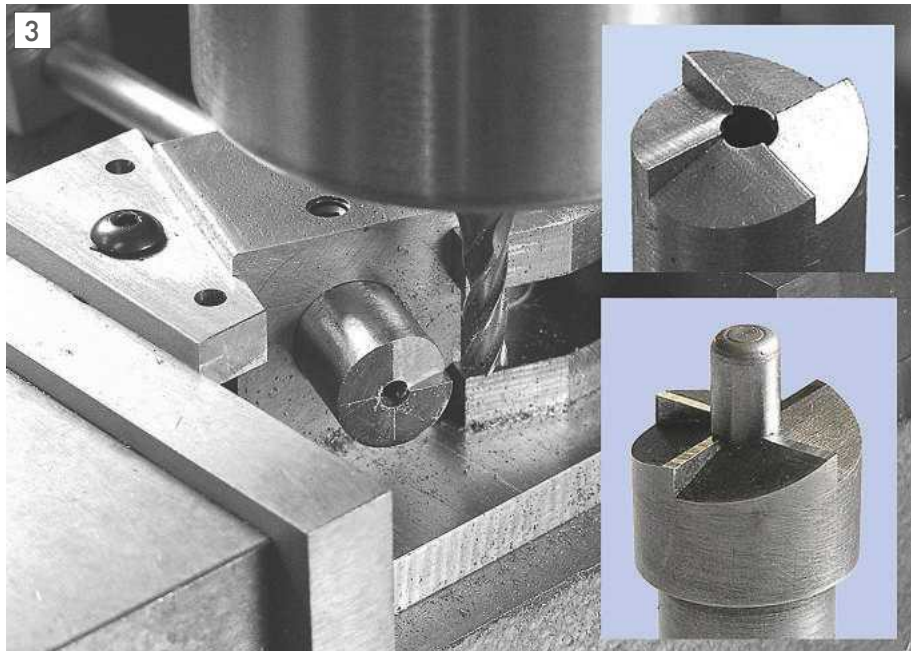
Use a diamond lap to hone the cutting edges

When making cutters from machinable tool steels like W1 and O1, do all the shaping you can – including edge grinding – **before** heat treating. This minimizes the danger of softening a treated tool by grinding after the fact. A hone is often all you'll need to put on a working edge.

Remember, machinable tool steels are not like HSS. O1 and W1 are very distant relatives of High Speed Steel, really a totally different material. For one thing, HSS is not machinable in the ordinary sense, so it has to be ground to the desired shape. For another, it can be ground to dull red temperature without affecting its performance in the slightest – a good thing if you are trying to grind, say, a single point threading tool from a 3/8 inch square blank of M2. That would take all day, possibly two, with the dainty technique we have to use for O1 and W1. Grind HSS as aggressively as you like. Finally, no matter what you've read elsewhere, never cool HSS by water quenching. It will likely be damaged by the thermal shock, and therefore more prone to failure in use.

Case hardening works, too

If you are out of drill rod, and need a special tool this minute, you can often do the job by case hardening any steel you happen to have on hand – 1018, even 12L14, whatever. A pound of case hardening powder goes a long way, which is good news in view of its cost. It is available from the usual specialty suppliers such as McMaster Carr. Case hardened mild steel stands up to a surprising amount of use, but the hardened case is only a few thousandths of an inch deep, if that, which means practically no grinding. Much better is to fully machine the tool in its soft state; then, after hardening, sharpen it by a minimal amount of careful grinding followed by hand-finishing with an oil stone or diamond lap – just as you ought to be doing with O1 and W1 steels. (In a pinch, you can even dispense with the grinding operation – go straight to the



Counterbore from W1 steel.

stone or lap instead.) The great thing about case hardening, compared to heat treating W1 and O1, is that it takes only a matter of minutes, with no need for tempering: heat the workpiece to 'bright cherry red', dip it in the powder, reheat to the same temperature, then quench. Just one caveat: make sure the work surface is evenly heated and uniformly covered with the molten powder.

Is it worth all the trouble?

Meaning, can tools made of W1 and O1 deliver useful results? Absolutely. Here's one example (photos 3 and 4) a special purpose 3/8 inch counterbore. Starting with a 5/8 inch rod of W1 (necked down to a 1/2 inch shank), it was fully machined in a simple 20° milling fixture, leaving only a few thousandths of material to be ground off in the sharpening process following heat treatment. The pilot pin, a hardened dowel, was installed after finishing. The tool shown here has survived five or six boring ops in 1018 steel without noticeable degradation. ■

FOR ADDITIONAL BACKGROUND

Steel Metallurgy for the Non-Metallurgist

John D. Verhoeven, Iowa State University (Publisher: ASM International). Looks formidable but isn't; highly informative, easy to read. Available from Amazon.

Heat Treatment, Selection and Application of Tool Steels

William E. Bryson (Hanser Publications). This is not the Walk-in-the-Woods Bill Bryson. Available from Amazon.

Iron-Carbon Phase Diagram MSE 300 materials

laboratory procedures
Dept. of Materials Science and Engineering, U of Tennessee, Knoxville

4

Holes made with the tool.

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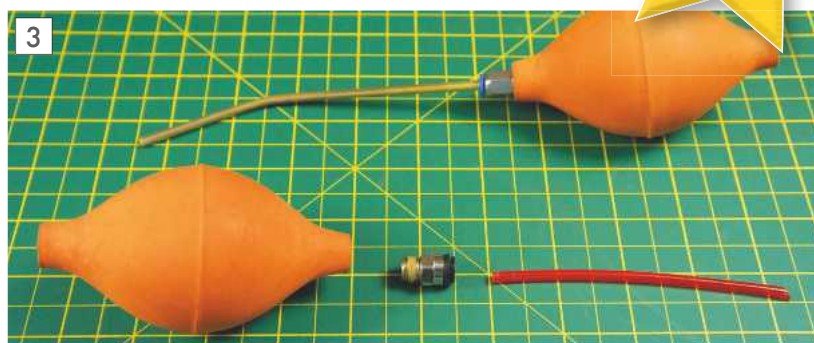
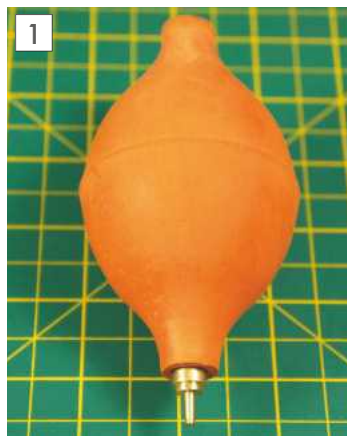
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This month's winning tip from **Bob Reeve** won't leave you gasping for air! He wins £30 of Chester gift vouchers.

As we get older we might expect to get a bit short of puff, but I didn't expect that to apply to that useful little gadget, usually known as a puffer (**photo 1**). These are inexpensive, available from several of our supplies and might be replaced without a second thought, but curiosity caused me to investigate why mine was getting short of breath. **Photo 2** shows the nozzle in close-up and the cause of the problem. During its working life the nozzle is in close proximity to mills, drills, saws and such like, sometimes getting a bit nibbled in the process. A new nozzle could be machined easily, but **photo 3** shows my solution which also improves the versatility of the device.

The 4mm push fit pneumatic fitting is inexpensive (available from MSC order number CJN-00171L) and the $\frac{1}{8}$ inch BSPT end is a push fit into the rubber bulb without modification. The delivery pipe is easily replaced can be made to suit the job in hand from any suitable soft material that will not damage the job or the cutter.

Why two puffers? Well, I actually have three, one each for mill, lathe and band saw. Why waste precious workshop time wandering around looking for something that costs so little? For me, unnecessary movement is one of the Seven Wastes in the home workshop just as much as in industry.

Bob Reeve

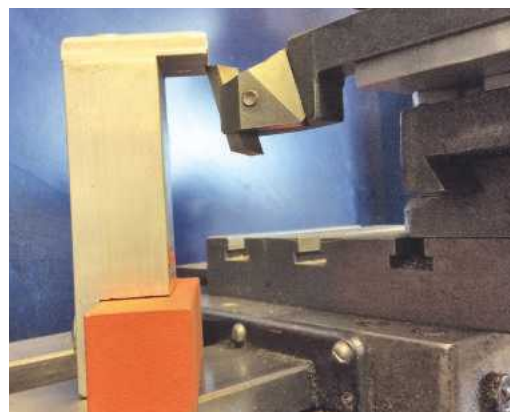
The first runner up of 2015 is **Adrian Secrete**. Many readers have discovered the joy of tangential tooling, this tip eases the height setting of these tools. **Adrian gets a Workshop Practice Series book as a prize.**

When using my tangential tool holder, to save time setting the cutter tip height after sharpening I made a simple jig.

The base of the jig is made from a permanent magnet and the height of the column is made to suit the recommended lathe cutting height.

After sharpening the cutting tool I place the jig on the lathe bedway and the magnet holds it in place, I place the cutting tool into the holder and raise it up until it contacts the overhang of the jig then tighten the locking screw.

Adrian Secrete



No more than one prize with a value of £30 will be given each month. By entering you agree your entry can be freely published and republished MyTimeMedia on paper or electronically and may be edited before appearing. Unpublished tips may be carried forward to future months. You will be acknowledged as the author of the tip. There is no guarantee that any entry will be published and if no publishable tips are received a prize will not be awarded. The decision of the editor is final.

made. A suitable lever is also required of reasonable length to enable the tool to be hand swivelled against the blank to create the spherical ball surface. In this case the large spanner provided with the Conquest Mill has been adapted for this purpose but any suitable length of steel flat bar can be used. **Photograph 1** shows the general set-up with an extended arbor holding a governor ball blank ready for turning. The length of the handle ensures good control under hand action. **Photograph 2** shows two prepared ball blanks each with a threaded stud at the rear and centre drilled at the other end for tailstock support (more on this later).

Figure 1 illustrates the assembled modified top slide arrangement and tool post. It will be noted that the new holes in the slide base block allow the top slide to be set off to one side of the cross slide with the rotation centre coinciding with the existing circular inset disc which is part of the cross slide mechanism. Details of the new holes required in the base block of the top slide are shown in **fig. 2**, but note the recessed hole on the underside to fit over the upstanding lug on the top of the circular inset disc. There is also a small threaded hole required in the base block at the rotation centre of this to accept a screw-in upstanding locator pin, tool tip high, which visually locates the cross slide position on the lathe centre line and which can be used to also locate the carriage location at the centre of the ball blank. The new tool post details are shown in **fig. 3**, hexagonal in plan shape, with a clearance cut away on one side where this reaches its clockwise limit of rotation and comes close to the projecting arbor. This allows the tool tip to reach closer to the rear of the ball and produce a smaller collar. The dimensions of the hexagonal shape of the tool post shown is to suit the large spanner mentioned above but this can be adjusted to suit any other similar form of spanner including open ended types. So apart from the mounting holes and the height to the cutting tool, the rest of the slide, tool post and lever arrangement can be whatever the user wishes or has suitable scrap box material for. Note that the modifications will have entirely no effect on the normal use of the top slide.

Initial Set-Up Procedure

The top slide has to be fitted onto the circular recessed disc in the cross slide using the cap screws through the new holes in its base making sure that the central hole on the underside fits neatly over the upstanding lug of the disc. The screws must be tightened to clamp the top slide to the cross slide but only just enough so that the top slide can be rotated, albeit a little stiffly. Fit the locator pin into the threaded hole and tighten down. With the ball blank securely mounted at the end of the arbor, the cross slide has to be adjusted to take the rotation centre with its attached upstanding locator pin across to the lathe centre line using the turned end of the blank or the tailstock centre as a visual guide for this and the cross slide locked when centred. With the top slide set at right angles to the lathe axis, the carriage is then adjusted to bring the tool

Fig. 1

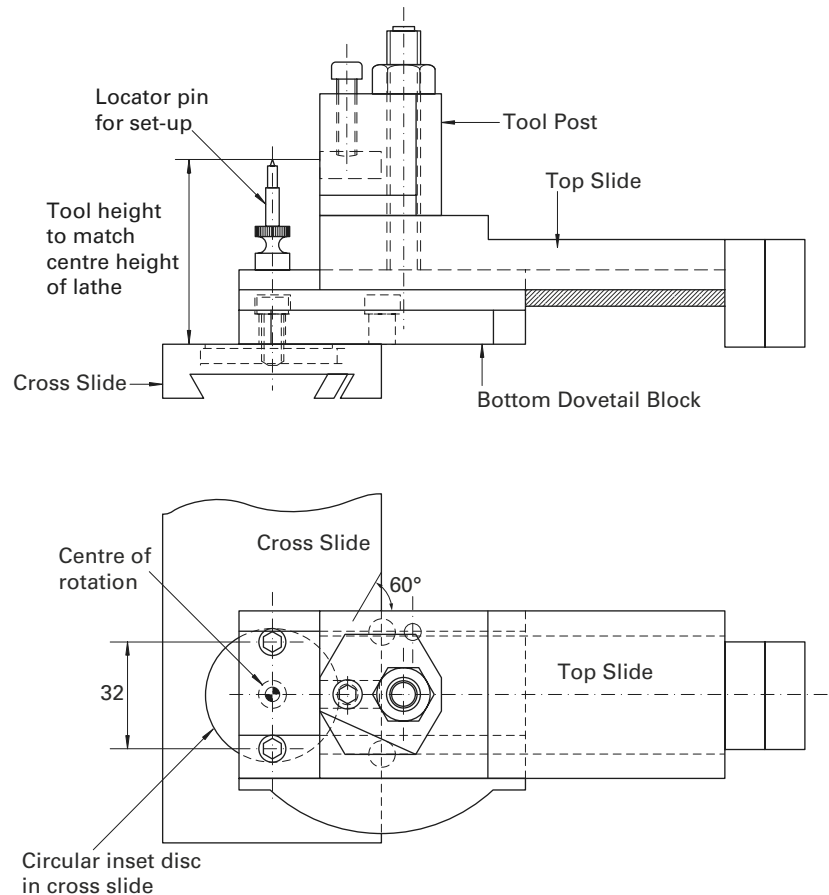


Figure 1 - Assembled Top Slide & Toolpost

Fig. 2

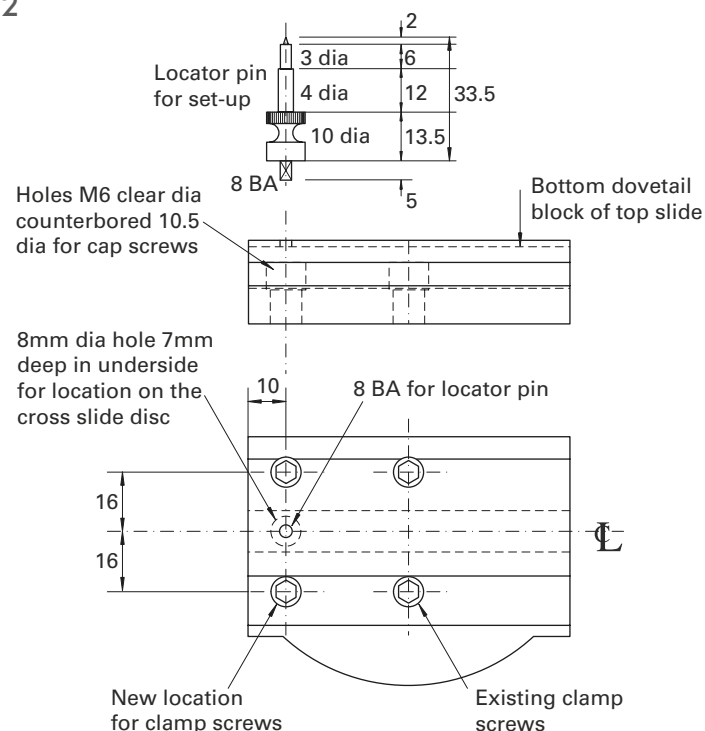
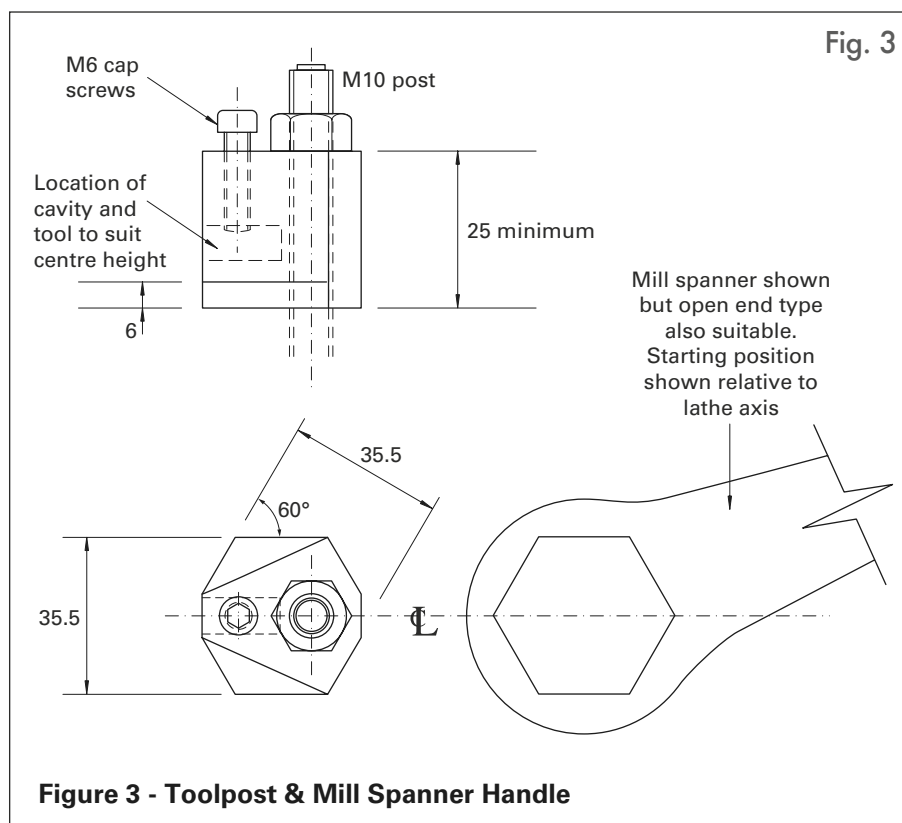


Figure 2 - Modifications to Dovetail Block also showing locator pin



arbor at its greatest overhang from the chuck, the first stage was to bring the tailstock centre into the end of the ball blank and proceed to turn only the rear half of the ball, remembering not to touch the cross slide adjustment or the carriage adjustment, thus using only the top slide adjustment to advance the cut. This is shown in **photo 3**. The collar to be seen on the rear of the ball is about 1 mm in depth. At completion of the rear half of the ball, the chuck jaws were released to allow the arbor with its half-finished ball to be moved in much closer to the chuck and the live centre replaced with a half centre. This second stage adjustment of the arbor gives enough access to nearly finish the ball and is illustrated in **photo 4**. Despite the use of the half centre, the amount of anti-clockwise swivel available to the tool tip in this position is a little limited by the close presence of the tailstock so the outer end of the ball could therefore only be partially finished to the limit of the tool clearance. It only remained at this point then to move the tailstock out of the way to allow completion of the finishing cuts. **Photograph 5** shows this final stage. It will be appreciated by the reader that the use of the tailstock with its half centre when the ball is so close to the chuck is optional depending on how stiff the thin rear threaded stud is to resist the cutting forces. If the stud is thought to be stiff enough, it is possible of course to go straight to the set-up shown in photo 5. The final outcome after a bit of polishing is shown in **photo 6** and as fitted to the completed governor in **photo 7**.

Alternative Machining Procedure

A good alternative to the method described for machining the governor balls is to carry out the entire operation in one go by keeping the arbor at its full overhang from the chuck without tailstock support but giving it lateral and vertical support from a travelling steady. Since the cross slide is locked in position, the steady does not actually travel at all and simply remains in the same position throughout. The general set-up for this is shown in **Photograph 8** which is for a much larger steel ball 24 mm in diameter. It will be noted here that I did not have a proper travelling steady to use for this and simply fitted a brass v-ended flat to a reversed

tip in line with the end of the ball blank. From that position the carriage can be adjusted toward the headstock by half the diameter of the ball that it is intended to turn and the carriage locked. This then is the starting position for turning the ball initially using only light cuts. During the progress of turning the ball it is necessary to frequently check the tightness of the screws holding the top slide to the cross slide. If these slacken too much, the radius of swing becomes somewhat irregular causing, vibration, chatter, poor finish and a possible dig-in.

Machining Procedure for Governor Balls

A particular problem with ball turning in this manner is the large amount of clockwise rotation of the tool tip required to create the spherical surface and the resulting large outstand distance of the

ball from the chuck making the whole set-up very non rigid and hence liable to producing chatter and a poor quality surface finish. To overcome this problem there are three fairly obvious ways of doing it; 1) using a very stiff arbor of substantial diameter at its full projected overhang from the chuck; 2) using a much thinner arbor which is given lateral support using a travelling steady, and 3) using tailstock support with a live centre for part of the operation. There are advantages and disadvantages with each of these approaches which will become clear later when I look at both the second and third methods in this article with suitable examples.

For the purposes of the immediate need for the governor balls, however, the third approach described above was the one adopted. This resulted in the turning process needing to be carried out in two distinct and separate stages. With the



Turning the rear of a ball.



Optional set-up for the 2nd stage to finish the ball with a half centre support.



Set-up for completion of the ball.

The two 14 mm diameter finished governor balls.

rear tool post and adjusted it to bear on the arbor. This was quite satisfactory but the use of the correct steady designed for the purpose would, I am sure, be a better proposition. The long handle, i.e. the mill spanner, is particularly useful when larger balls such as this have to be turned as the cutting forces involved are more easily controlled with the long lever using relatively light hand guidance. The result after finishing to a moderate degree is shown in **photo 9** with its M5 removable mounting stud.

Conclusions

The modification of the top slide for the purpose of ball turning is extremely simple and can therefore probably justify the small amount of work that goes into making it as against the purchase of a proprietary attachment. It is very convenient to use with very little set-up time involved and, with care, does a fairly good job. The two slightly different approaches to the working procedure as described in the foregoing seem to produce equally good results. It has to be said that although method 3 involving the use of the tailstock for support needs a two stage operation and takes a little more time to complete, the excellent rigidity obtained at both stages gives greater confidence to taking reasonable cuts with very little vibration. Using instead the travelling rest (i.e. method 2) allows the work to proceed more quickly in one operation and is no doubt more conducive to accuracy of spherical truth. There is however more vibration and hence a risk of chatter with a consequent need to be careful to take relatively light cuts. As for method 1, working entirely without the support of the tailstock or the travelling steady, would require that the arbor used be very sturdy indeed as the length of overhang from the chuck is substantial. It is to be noted in that context that it is not really possible to use a standard fixed steady to help that problem as it would greatly interfere and/or obstruct the turning of the ball which requires the operating handle to be swivelled round



The completed governor on the McOnie engine.

close to the chuck for each cut. The arbor would thus have to accept all the tool cutting forces entirely by itself.

If success is measured by the quality of the result and the fact that the continuance of the project in hand has been satisfactorily progressed using only in-house equipment, then the idea to convert the top slide to this extra duty has, without doubt, been a reasonable success. It may not compare with the proprietary product but it is quick to make and gives satisfaction when it is seen to be capable of doing the job. A final word of warning is in order however; the hand holding the operating handle frequently comes in close proximity to the revolving chuck and it behoves the operator to carefully observe the possible danger of a really nasty knock on the knuckles and take appropriate care to prevent that. Where a full protective chuck guard is in use, then there should be no real concern in this respect. If no guard is available, the use of an ER collet chuck or MT collets rather than the three jaw would go a considerable way to reducing that risk. In this context it may be of interest to anyone

trying method 1 that the stiffness of a cantilever arbor varies directly as the fourth power of its diameter, e.g. a 20mm arbor is twice the diameter of a 10mm arbor but, for the same length and material, it is 16 times stiffer and will hence deflect against cutting forces only a sixteenth of that of the 10mm arbor.

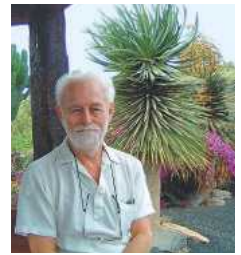
As so often happens, the need to make some part which needs a special attachment or tool is frequently the driver for creative thought about what forgotten or little used item might be lying around in the workshop that can be brought out and used for a new purpose. Unlike some who get special pleasure in making tools rather than models, I find I need the extra spur of 'dire need' before I do anything about it. Now, the ready availability of this facility has me now looking around for excuses to turn balls where before I just didn't think about them at all. Silly, isn't it? ■



Set-up for turning a ball using a rear steady for support.

The finished 24mm diameter ball.

Chain Drilling Marker Jig



Peter Wilton offers a simple jig to ease the task of drilling a series of closely spaced holes.



A Chain Drilling Jig.

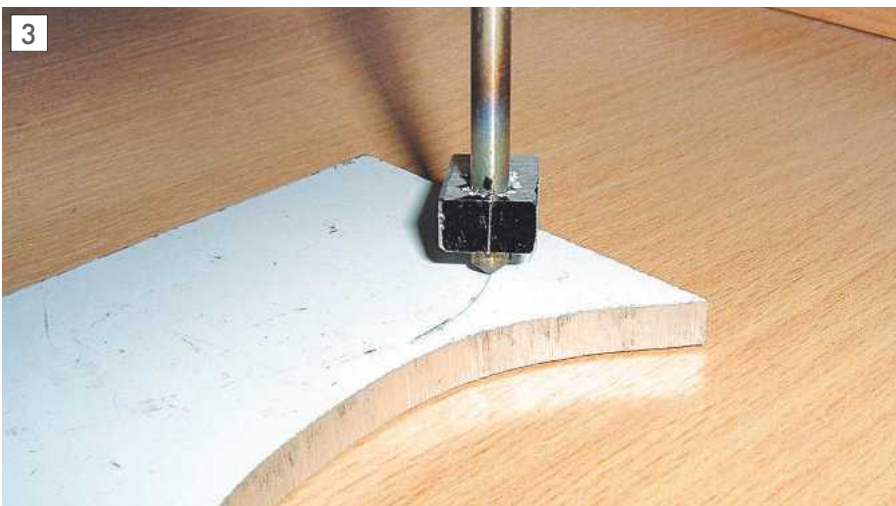


Three Chain Drill Markers.

Once in a while the need to drill a set of holes adjacent to each other occurs, at least to me. More often than not it is to cut a flywheel blank from sheet of steel or alloy. My bandsaws (yes, I have two elderly Burgess bandsaws, one for wood and one modified for metal) are not very powerful and need a lot of help coping with $\frac{1}{2}$ inch or more steel so a set of pre-drilled holes does the job. I hope that somebody is helped by this article.

I would like to think the photos are self-explanatory. Basically the jigs consist of a piece of alloy about 6mm thick, two holes of the required size carefully drilled adjacently on the centre line. The short bar, the guide, is pushed through so that it will locate in the first hole of the chain. The longer bar has a 45 degree point ground to the front end and has been hardened. This bar is pushed through the alloy plate just far enough for the point to be easily visible (see **photo 3**). When happy with the set up, I used a sharp punch to centre pop the alloy around the bars to fix them, Loctite or super glue would do instead.

I made three sizes just in case of a need arises, $\frac{1}{8}$ inch, $\frac{3}{16}$ inch and $\frac{1}{4}$ inch. In use they are a bit laborious but accurate. Procedure is to drill the first hole as accurately as possible on the scribed line, then put the jig into the hole and align the point on the line, a tap with the hammer to mark the hole position and then use a centre punch properly to guide the drill bit. ■



Chain Drilling Marker Setting Up.

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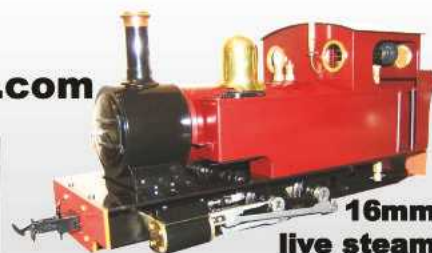
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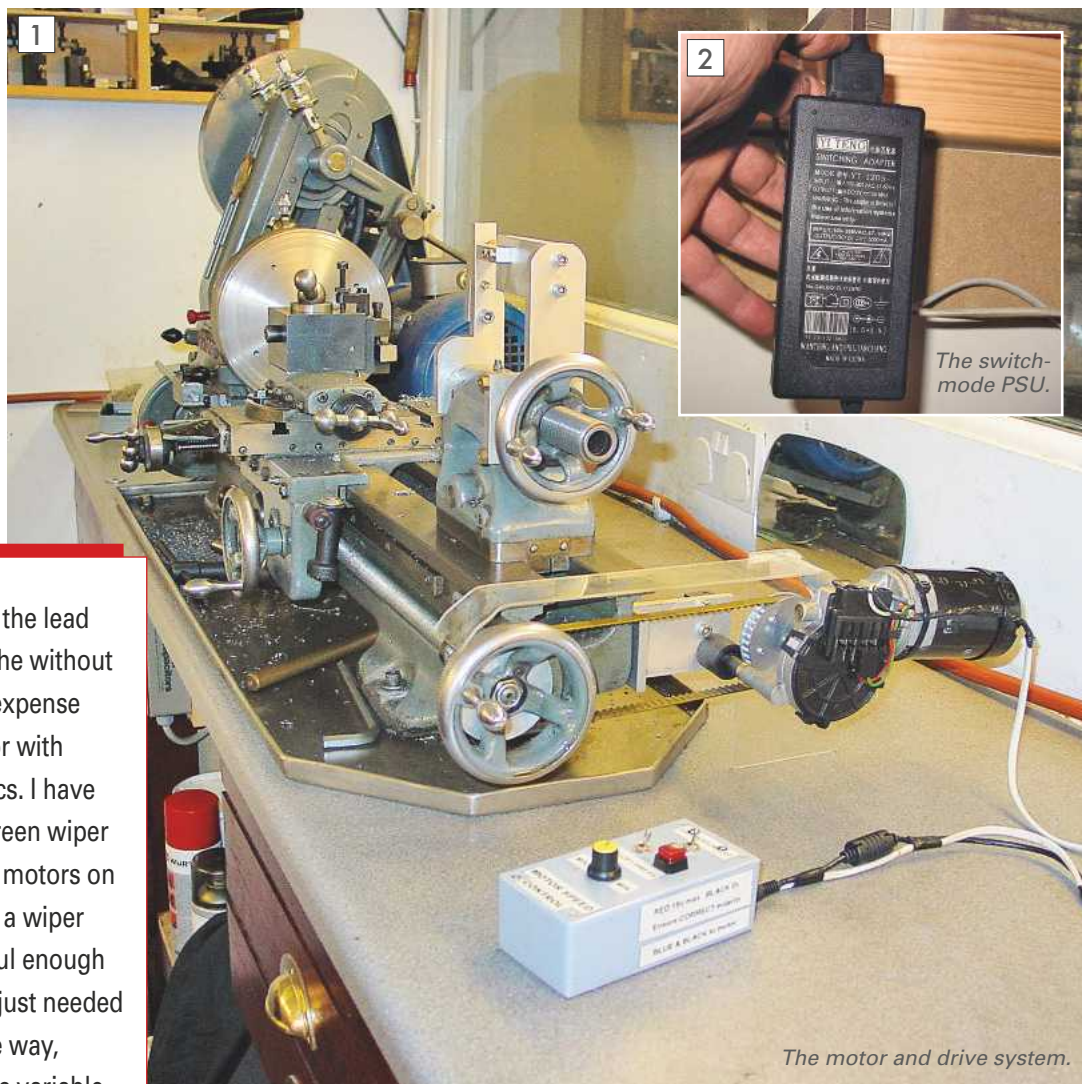
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Rich Wightman and Julian Harrison combine their talents.



I wanted to power drive the lead screw on my Myford lathe without going to the trouble or expense of fitting a stepper motor with the associated electronics. I have used 12 volt car windscreen wiper motors and radiator fan motors on other projects so I knew a wiper motor would be powerful enough and do the job nicely. It just needed to be controlled in some way, forward and reverse plus variable speed if possible. The mechanics I could do myself but the electronic side of things were a bit of a mystery. My mate Julian looked into it and said he could build a controller that would give me the required functions. Between us we worked it out and built a very useful accessory. **Photograph 1** shows the completed motor and drive system.

The following article is how I achieved it with the help of Julian. As with most of my projects there are no plans as such, as it was a trial and error type of project made up as I went along. It will be mostly photos, but I will include a few sketches.

A Powered Lead Screw for a Myford Lathe

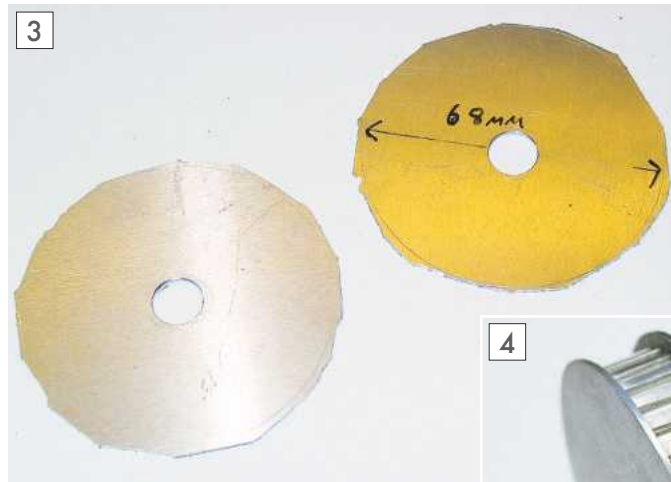
With the gear cutting now mastered, shown in the Model Engineer April-May 2013 issue (ref. 1), I could get on with building and fitting a motor to power drive the lead screw. Although this is designed to fit a Myford lathe, the idea could be easily adapted to fit any lathe. The power comes from a car windscreen wiper motor. They are of course 12 volt dc which means a 12 volt power supply will be needed. This can be in the form of a battery, a transformer or a power supply. I picked up a 12 volt 5 amp power supply off eBay for £5.00 (photo 2). The motor itself could be found on the same site, sourced from a scrap yard or salvaged from a car that is being scrapped. They are all pretty much the same with slight differences depending on the make and model of car. As such I won't delve into the wiring of the motors as there are differences but they basically work the same. Playing about with 12

volts is reasonably safe compared to the obvious hazards of 240 volts as long as common sense is used. The motor I used has three wires giving two speeds. Usually there are five wires with two of them giving the 'Park' function for the wipers. When the wipers are switched off they keep running until they reach their park point at the bottom of the screen. It's not too difficult to work out with a bit of trial and error. A multi-meter with a sounder function will find the two park switch leads and these can be chopped off as they only go to a micro switch and are not needed here. Using some power from a battery or power supply the other leads can be connected to find the best suited speed. Beware of the casing as this is normally the earth and will spark if touched with the cables. The different leads go to different windings in the motor to give different speeds. Choose the speed and mark the cables used. If it suits use the casing and

one cable but be aware this will push the live into the casing first in one direction. If you have a ground earth on your lathe then this will earth the power. To avoid this you will need to insulate the motor from the lathe which would mean using plastic for the mounting bracket. It is much easier to use two of the cables. The cables not being used can be chopped or a better idea would be to insulate them so they can be used at a later date if you want to alter the higher speed. Another way to identify the cables and switch is to remove the cover on the end of the gearbox and trace the cables. Power will still be needed to check your choice of cable. I chose to use the faster of the two speeds which turned out to be the right one to use for my lathe. It's a simple matter to change 2 wires if the slower speed is required but with the variable speed controller I can go as low as virtually zero with a reasonable top speed.

I used a 100 tooth 500mm long belt for this project. The belts can be sourced online along with the gears if you don't fancy making them.

The first job to be tackled was to make a couple of gears. I chose to use a 40 tooth gear on the motor and a 40 tooth gear on the lead screw giving a 1:1 ratio. It was all experimental so I had to take a guess at what gear sizes to use. As it turned out the gear sizes were a good choice. Both gears



The unfinished gear flanges, cut from sheet.

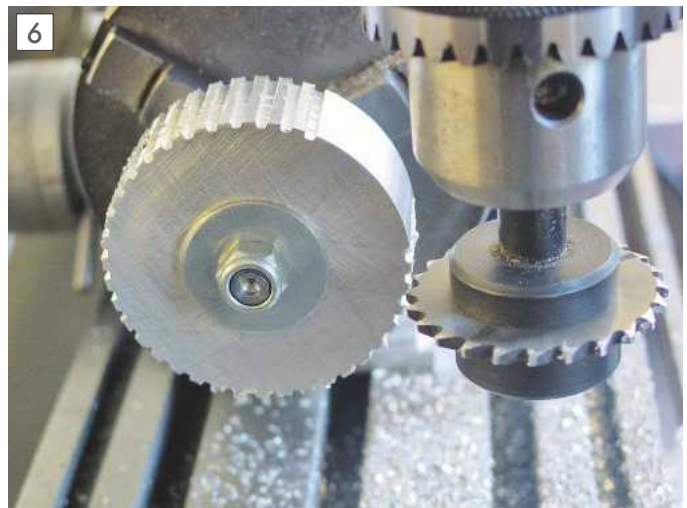
A finished 'gear' for the toothed belt.



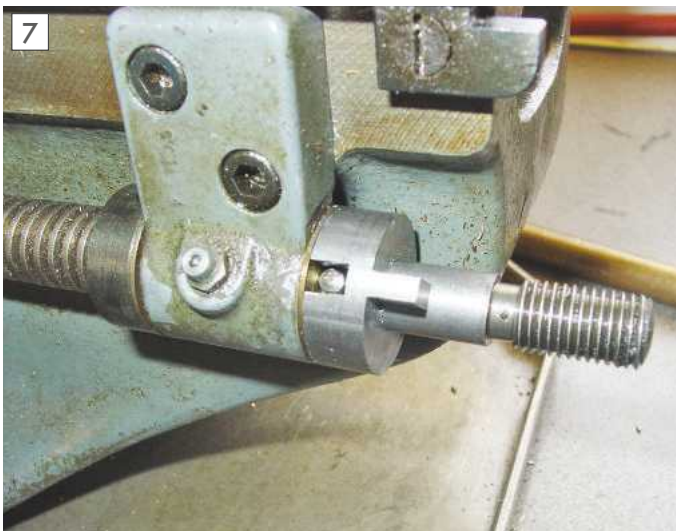
are flanged. The flanges, 4 in all, are made from 1mm aluminium (photo 3) cut from sheet and turned to size on a mandrel. I turned them two at a time using the two gears to clamp them onto the mandrel. The flanges on the hand wheel gear are simply super glued on (photo 4), as this one will be drilled and bolted to the hand wheel while the gear on the motor has the flanges pop riveted on (photo 5). I'll just show one photos of the gear cutting here, for a full description please see my previous article (photo 6).



Pop riveting a flange.



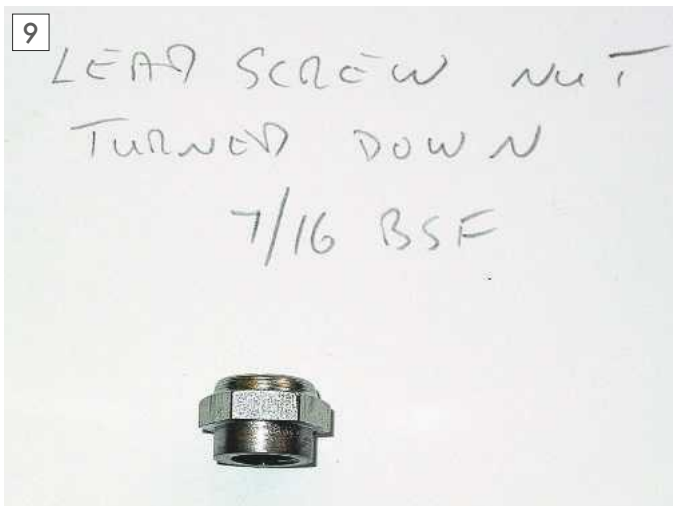
Cutting the toothed core of a gear.



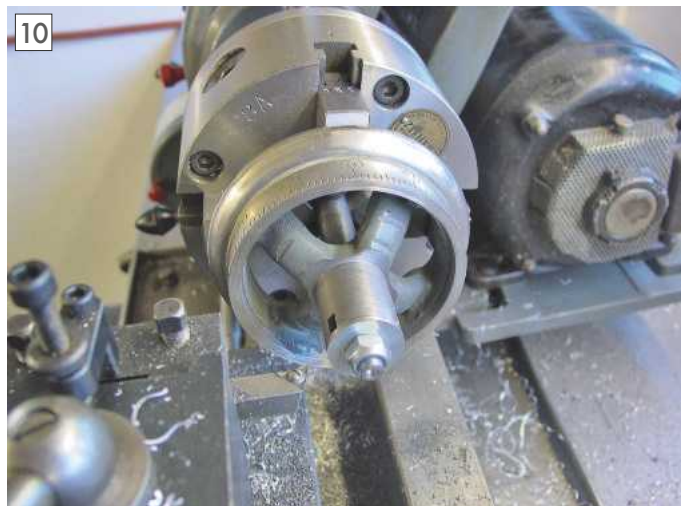
The leadscrew spacer.



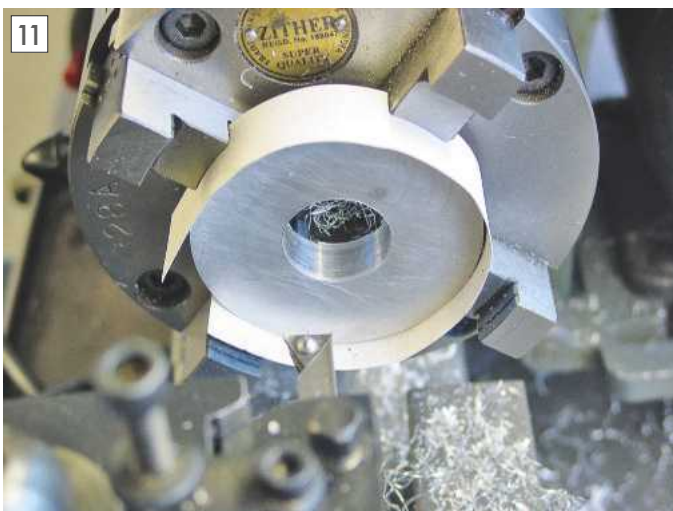
Counterboring the handwheel.



The modified leadscrew nut.



Finish machining the handwheel.



Boring a gear to fit the handwheel.



Drilling gear fixing holes in the handwheel.

Fitting a gear to the motor was fairly easy. The motor has an 8mm threaded section under which is a tapered splined section leading into the motor shaft. Bore the centre of the gear 8mm then countersink, I used a large centre drill to countersink which has a 60 degree angle similar to the taper on the motor. With a couple of drops of thread lock compound the gear can be tightened on to the motor shaft. The splined tapered section will bite into the aluminium gear and hold firm. Fitting a gear to the lead screw proved to be more of a challenge. I could of course do away with the lead screw hand wheel altogether and just fit a gear in its place but I wanted to retain the hand wheel so that the lathe could be used in its normal manual fashion. The hand wheel on a Myford is held on with a self-locking nut which is not fully tightened but used to adjust backlash. The hand wheel on my Myford lathe needed to be modified. There isn't quite enough room to fit the gear inboard which is where it needs to be to keep it out of the way and allow the lathe to be used manually. To gain a bit of room the hand wheel must be moved outwards. I machined a spacer (photo 7), to the dimensions in fig. 1 which gave me enough room to fit in the gear but not enough thread on the lead screw to fit the nut so the hand wheel had to have some material machined away and

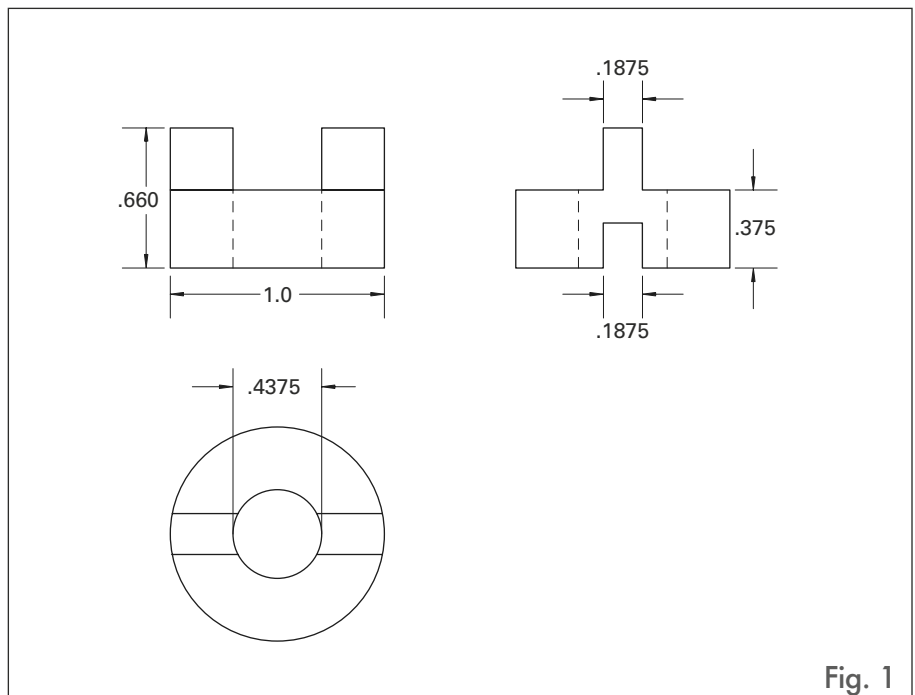
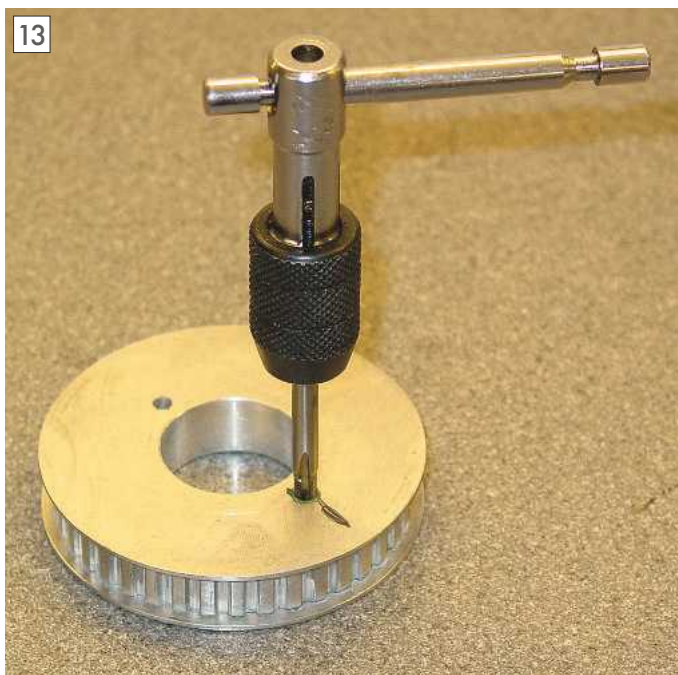


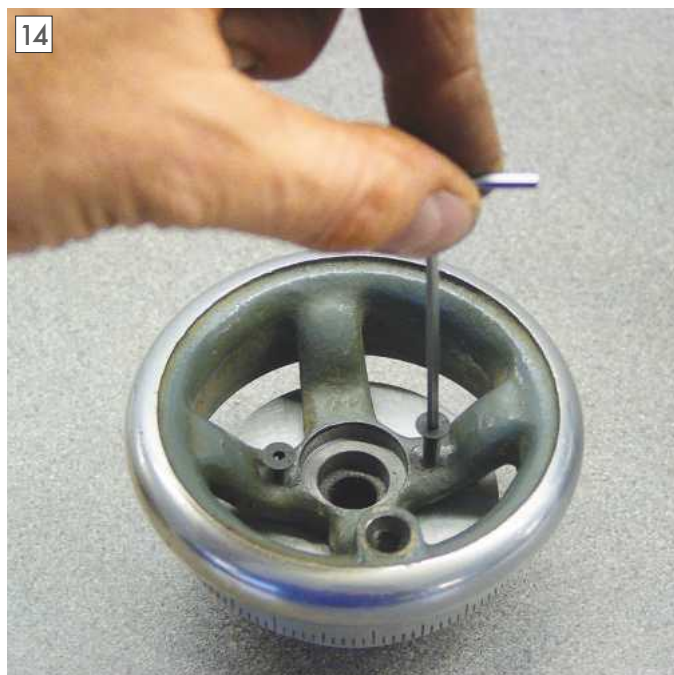
Fig. 1

counterbored (photo 8). The nut was then machined to suit (photo 9). The hand wheel was then mounted on a mandrel and turned down until a smooth finish was achieved, the finished size is not

important as the bore of the gear will be machined to suit, (photo 10). Machine the bore of one of the gears to suit (photo 11). Drill two 4mm holes through the hand wheel (photo 12), and then fit the



Tapping the gear.



Assembling the handwheel to the gear.



A trial fit to check clearances.



New and old pointers compared.

gear and spot drill. Drill the gear tapping size for 4mm. Remove the gear and tap 4mm. (**photo 13**). Drill out the hand wheel a clearance size for 4mm and countersink. Assemble the 2 parts with a couple of countersunk socket heads screws, (**photo 14**). A trial fit on the lathe to check everything clears ok (**photo 15**). Because the hand wheel is now further away I made a new pointer (**photo 16**). It's copied from the original, just a little longer and shaped so that I can remove the belt easily. After blacking a line is marked then fitted to the lathe. By slackening the screw it will tip up enough to remove the belt (**photo 17**).

To be continued...

REFERENCE

1. *Model Engineer* issue 4454, Volume 210. Cutting Timing Belt Gears. Wightman, R.



The new pointer is easily moved to allow belt fitting.

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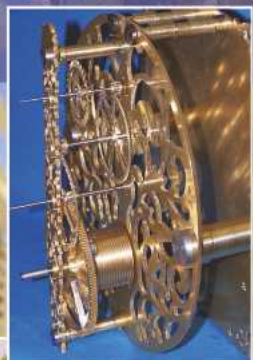
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Threaded Inserts and other **Hot** Topics



Mark Noel grows tired of tapping.

This article describes the use of threaded metal inserts as a speedy and economic alternative to the tiresome manual creation of tapped holes. These versatile components are particularly suited to the joining of plastic and soft alloy components, and are available in a range of sizes and specifications to suit most applications. The development of a heated insertion tool (**photo 1**) led unexpectedly to some other gadgets, one of which has proved to be a welcome addition to my chilly workshop this winter.



The heat staking tool in action. A set of brass M4 threaded inserts are being heated and emplaced into a PVC component. The ATX power controller also displays the stake's operating temperature.

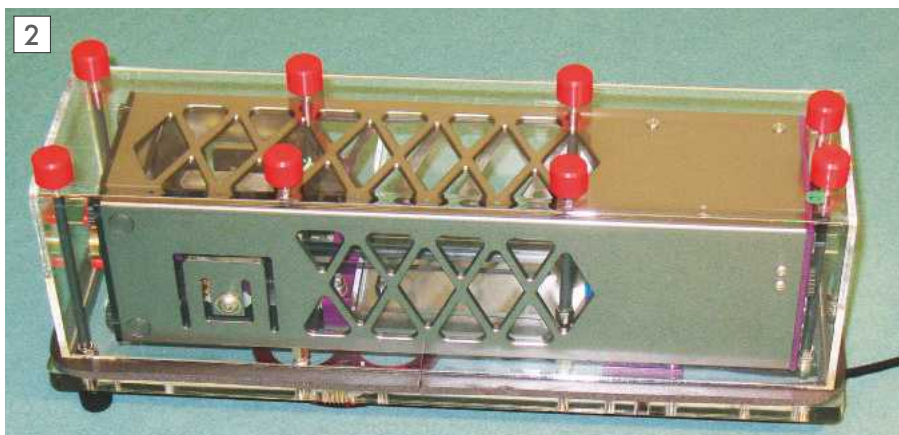
My main hobby interest is the design and construction of scientific instruments, in particular devices for use in geophysical research. A recent project was the construction of a sensitive seismometer for detecting the microscopic ground motion that results from distant earthquakes. The project was a success and led to a small commercial venture in

which I now produce these instruments for amateur seismologists wanting to monitor the shakes and quakes of the tectonic plates that shape our world (**ref 1 & photo 2**).

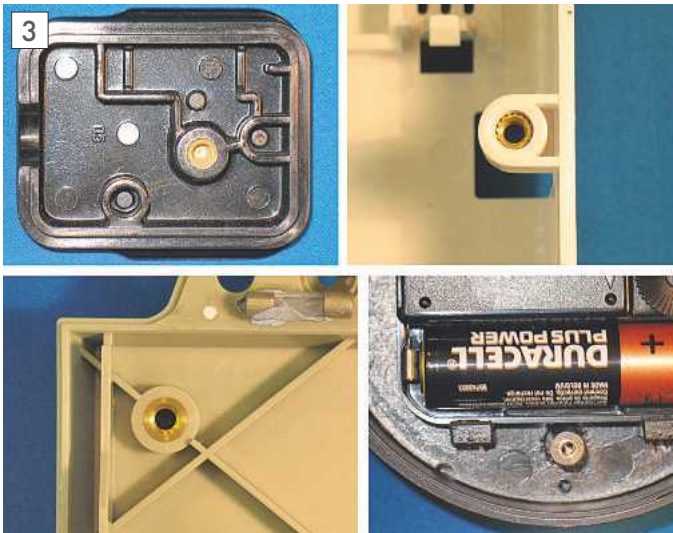
The seismometer mechanism is contained inside a clear acrylic cover that protects it from air pressure changes, dust and sudden fluctuations in temperature. The lid is secured with eight

knobs, tapped M4 and sealed with an O-ring. While building the first batch of instruments, I soon realised that the seemingly trivial operation of tapping dozens of knobs was taking a disproportionate amount of time and risking a repetitive strain injury. Of course, I could have built or purchased an automatic tapping machine, but neither the time nor the cost required could be justified, given that I was only struggling with making knobs! While repairing our vacuum cleaner I noticed that each threaded hole in the plastic casing had been engineered with shiny brass plugs, tapped to size and incorporated into the moulding. The result is a durable female thread with much greater strength than the parent plastic, and which does not require any manual or machine tapping operation in the factory. This pointed the way towards a solution to my problem.

When I dismantled (and re-assembled!) some other domestic appliances I found that these 'threaded inserts' are widely used to create fastenings in items as diverse as mains plugs, TVs, printers and mobile phones (**photo 3**). More chunky versions are found pressed into modern timber furniture where their purpose is to distribute the



My VS1 seismometer which detects the sub-micron seismic waves arriving from distant earthquakes.



Examples of threaded inserts incorporated into various electrical appliances. Clockwise from top left: Mains plug, TV casing, desk clock, radio.



Examples of Anchor inserts. The BW2015 part on the left is the one used in this project.

stress at important joints. Most inserts are manufactured in brass or steel and designed to be deployed as follows:

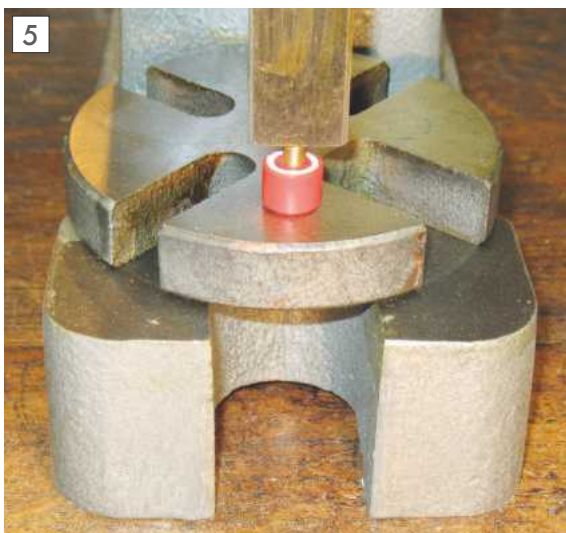
- **Moulded In**, by suspending the insert within the die during the injection process. The domestic electric plug contains an insert incorporated by this process. Such inserts must be closed at one end to prevent flow of molten plastic back into the thread.
- **Pressed in Cold**, into a suitably sized hole created by or after the moulding or casting process. This is a lower-cost method that does not require modification to the injection mould. Suitable inserts can be open or closed, since blocking flow does not occur.
- **Pressed in Hot**, into a suitably sized hole cast or drilled into the plastic moulding. This method is termed 'Heat Staking' and requires a special tool that heats the insert in order to melt it into the component. Of intermediate cost, this process also permits changes to the insert design without major modification to an existing die. Suitable inserts can again be open or closed at the inward end, but if open, the staking tool needs to block this aperture to prevent flow.

Threaded inserts are not a modern invention but can trace their history back to the days of Bakelite telephones and switchgear in the 1920s, when this revolutionary new plastic proved too weak for tapping holes directly. Since then, inserts have found widespread use in industry but are rarely used in our workshop projects. Trawling the internet for a supplier of small quantities, I came across Anchor Inserts, a British manufacturer with a huge catalogue that extends over a wide range of thread sizes, lengths and materials, with a choice of knurls, ribs and teeth to suit various applications (ref 2). I discussed my problem with Anchor's technical expert, Austin Wade, who kindly sent a selection of M4 inserts to experiment with (photo 4). The final choice was the 7.9mm long Anchor model BW2015 which could be pressed cold into a 5.7mm diameter hole drilled in the seismometer's PVC knob using my 1 Tonne arbor press (photo 5). These brass inserts are machined with 4 barbs on the circumference to resist pulling out, combined with a band of axial knurling to resist turning of the insert. Having made the decision, I purchased a pack of 300 and completed a batch of

seismometer knobs in record time, changing what was previously a chore into a fun task (photo 6).

Readers of this magazine will be very familiar with the design of Myford and other small bench lathes, equipped with a quick-change toolpost and perhaps even a tailstock turret. In contrast, the specialist lathes used to produce threaded inserts are designed for rapid tool changing and automatic stock feed to permit fast turning, boring, knurling and chamfering to consistent and precise standards. Such specialised machines are unrecognisable to most home engineers and can achieve a rate of production of from 7s to 25s per insert, depending on the part's size and complexity (photo 7). Making each insert generates similar or slightly more swarf than the weight of the part itself, but all swarf is washed and together with the cutting oil is recovered for recycling. Occasionally Anchor even make special brass inserts with antique threads for the renovation of old Bakelite telephones.

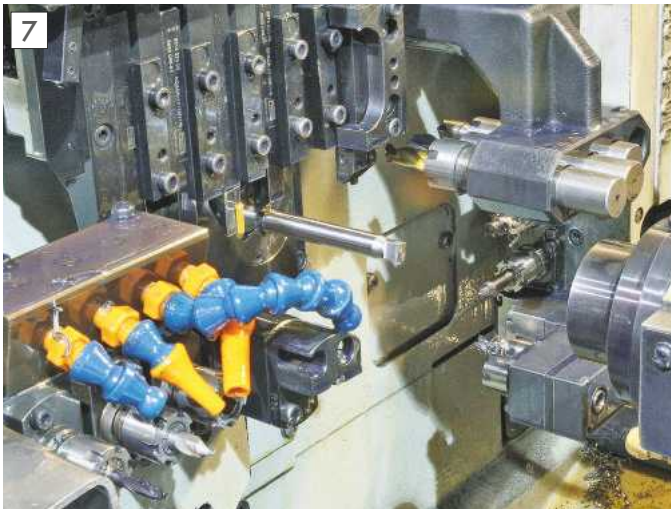
Cold pressing of inserts is only appropriate for compliant thermoplastics, such as PVC or ABS and not for brittle materials such as acrylic, or when the hole to be threaded is near the edge of a part, risking a crack or more serious breakage due to the forces involved. In such cases the process of heat staking that was mentioned earlier is the preferred option. It is important to recognise that this method can only be used for the class of materials termed 'thermoplastics' (which can be remelted), as opposed to 'thermoset' plastics which are formed from ingredients that react and fuse together during the high temperature moulding process (and which cannot be remelted). It is this type of thermal stability which makes thermosets ideal for moulding kettles, plugs,



Arbor press used to cold-press a threaded insert into one of the seismometer's PVC knobs.



A batch of seismometer knobs fitted with M4 brass inserts.



The automatic lathe used by Anchor Ltd for the production of threaded inserts.



The Enlight 150 Watt ATX power supply used in this project.

hairdryers and other hot appliances. As you can imagine, heat staked inserts are more intimately bonded to the host part and therefore can sustain greater loads in a finished assembly. I have a number of projects planned in my workshop where this will be a requirement, and so I decided to design my own heat staking tool. As the project developed it diversified considerably, eventually resulting in two more devices which have proved valuable additions to my workshop. As ever, I have tried to keep the cost to a minimum and to use recycled parts wherever possible.

The Heat Staking Tool

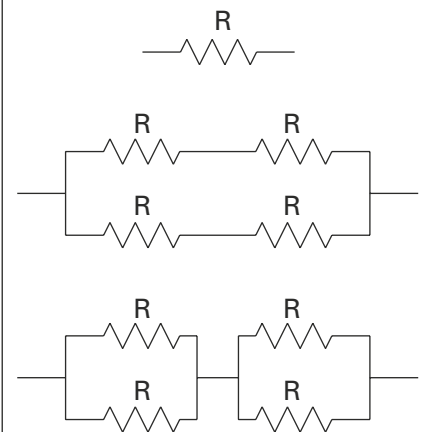
The main purpose of this tool is to hold and then heat the threaded insert to a sufficient temperature that it enters the pilot hole with little force, while plastic flows into the flutes and knurls to complete the bond. Hence, key requirements are the means of raising and monitoring the temperature, and guiding the insert into the hole. I decided to limit my ambitions by using my existing pillar drill to drive the insert, leaving only the problem of heating the insert and measuring the temperature. In this context the figure of interest is the 'Glass Transition Temperature' or T_g for the thermoplastic, which is the point at which the material softens to a rubbery state, rather than fully melts to a liquid. Values of T_g for the common engineering plastics which we generally encounter in our workshops are listed in **table 1**.

Figures for a comprehensive list of plastics are given in **ref 3**. Before embarking on the construction of your own

heat staking tool it is important to note that some plastics give off hazardous fumes when heated and so provision should be made for operation in a well-ventilated space. The risks associated with heating certain plastics are detailed in **ref 4**.

Glancing at the table above, it can be seen that most thermoplastics we are likely to handle have transition temperatures below about 130 degrees C, with only acetal and polycarbonate requiring a much higher value. However, since these materials are actually chosen for their toughness, they are unlikely to really need a threaded insert fastening, and I therefore decided to exclude these higher transition temperatures in the tool's specification. So what heat source should we use? A gas burner offers power but lack of fine control, leaving an electrical heater as the ideal candidate. Rather than dismantling my wife's hair dryer in the search for suitable wire, I decided that the more harmonious approach was to purchase a set of aluminium-bodied power resistors with a high temperature rating and mount these on a solid block of brass to form a compact heat source. Such resistors are flanged for chassis-mounting, are relatively inexpensive, and can be found rated to a temperature of 200 degrees C, which suits this project perfectly. For a supply of V volts, connected to a resistor of value R ohms, the power dissipation is V^2/R watts and the current through the component is simply V/R amps. An array of identical resistors each of R ohms, can be wired in combinations of serial and parallel such that the total resistance is still R , while increasing the power dissipation (**fig 1**). Of course, we still need a power supply able to drive current through the resistor array, and one which must be controllable to

Fig. 1



Various methods for connecting arrays of resistors, each of R Ohms, into parallel-series combinations, such that the resultant resistance is still R Ohms.

maintain a set temperature. A suitable component that can be obtained for zero or very low cost is the ATX power supply found in desktop PCs. Despite their electronic sophistication, even a new 600 Watt ATX unit can be bought for under £20 and they can even be salvaged free from your local amenity site or computer repair shop. I extracted an Enlight ATX unit from a broken Windows 95 computer, reckoning that the 150 watt output would be ample to raise the heat stake to a sufficient temperature (**photo 8**).

To be continued...

Table 1	
MATERIAL	T_g , °C (approx.)
ABS	110 - 125
Acetal	175 - 185
Acrylic	~ 110
Nylon	40 - 60
Polystyrene	90 - 110
Polythene	70 - 80
PVC	65 - 85
Polycarbonate	140 - 150

SUPPLIER REFERENCES

1. The VS1 seismometer is built to order by Rockwave: www.rockwave.co.uk
2. Anchor inserts manufacture and supply a vast ranges of metal inserts. The minimum pack quantity is about 100 parts. For further details visit: anchorinserts.co.uk
3. A comprehensive list of transition temperatures for a wide range of polymers is provided by Perkin Elmer at: www.perkinelmer.com/CMSResources/Images/44-74863TCH_MPTGAndStructureOfCommonPolymers.pdf
4. The hazards of fumes released when plastics are heated are documented by the UK's Health and Safety Executive at: www.hse.gov.uk/pubns/pps13.pdf

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The Metal Master (Impetus) Machine Tool

Mike Philpotts introduces an unusual multipurpose machine tool in an article which accompanies a detailed set of plans to be found at www.model-engineer.co.uk/metalmaster

Once in a while someone designs something really innovative which at first sight you could think would take the world by storm. Sadly because of entrenched viewpoints, vested interest and maybe a lack of marketing skills such good ideas do not always achieve the recognition they deserve.

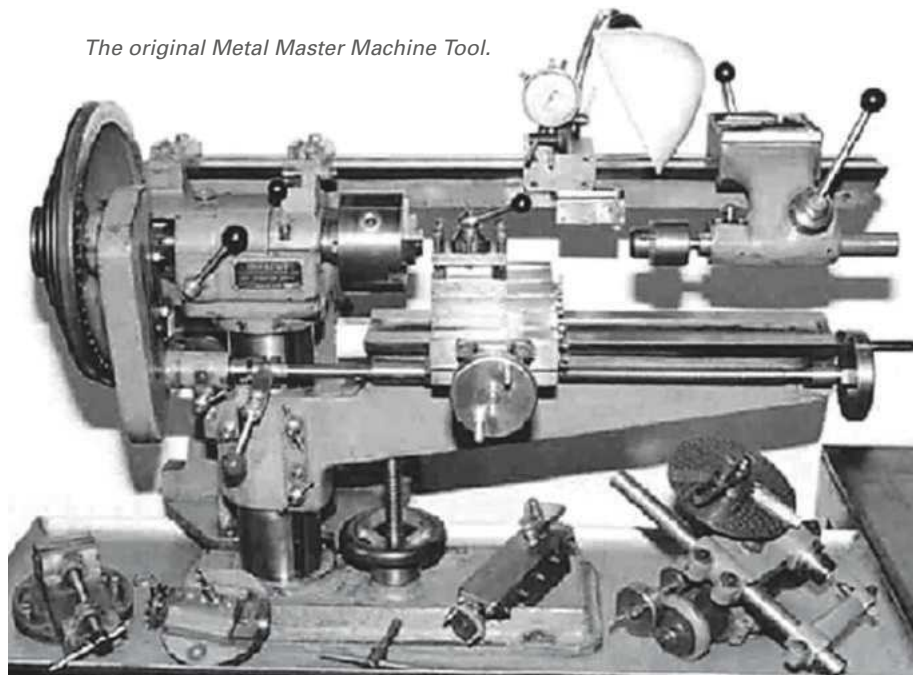
The Metal Master (Impetus) machine tool by David Urwick is one such innovation. It is still not clear why this idea did not take off. The machine is ideal for the small home machinist workshop and would avoid the somewhat larger investment in cash and the space required for multiple machines to achieve the same manufacturing capability.

As a tribute to the man who designed the machine a group of us have compiled a document set to enable anyone to reproduce the machine. Some people, recognizing the uniqueness of the design have produced a set of castings for the major components. Others have adapted the design to develop their own modern version of the machine (e.g. Alan Jackson's Stepperhead).

History of the design, drawings and manufacturing notes.

Originally conceived in the early 1950s by David Urwick, the design was well documented at the time and revisions

The original Metal Master Machine Tool.



made resulting in the hand drawn manufacturing set included with these notes was finalized in the 1980s.

Unfortunately, information, materials and documentation related to sporadic documentation efforts have appeared and disappeared on a number of websites over the past dozen years or so. It is hoped that by pulling the various sources of information together and giving it some structure we may encourage more to have a go at making and building this truly unique machine.

The design was certainly revolutionary and it was used as a basis for the larger Labormil machine. That machine was marketed for the small jobbing machine shop or as a millwright's machine tool.

On that basis the Urwick Metalmaster would be an ideal machine for the model and experimental engineer. However, things mostly never turn into an ideal solution without luck, money and persistence. Dyson had to fight to ensure his designs weren't either rubbish or stolen by others.

Urwick included in his machine many simple ideas that should have put it at the top of its chosen market. So remembering

that not always do the fastest win the race nor the mightiest win the battle, we submit these manufacturing notes for the Urwick machine for anyone's scrutiny so they can utilise some of David's ideas or make a replica of the machine themselves.

The orthodox method of making the patterns for the castings might be prohibitive. The use of expanded polystyrene as expendable patterns using a hot knife or 3D CNC might be the way to go.

Descriptions and images of the Metal Master (Impetus) and Labormil are on the www.lathes.co.uk website.

www.lathes.co.uk/metalmaster/ and www.lathes.co.uk/labormil/

Articles about the Metal Master and some of its machine elements written by David Urwick appear in these editions of *Model Engineer*.

A Free- Lance Lathe 1st March 1951

A Revolutionary 4th January 1974

A Keyway Breakthrough 15th August 1980

METALMASTER - A Zero Taper Machine Tool 2nd July 1982



Some recently produced Metal Master castings from the new 3D model.

Mick Collins, who bought David's own original machine, agreed with David Urwick's widow that the drawings should be made public and that each user of the drawings would make a small donation to her for doing so. It is not clear how the donation was to be made for this 'shareware' or 'Open Source' material. It has been agreed that, unless a relative of David Urwick can be found, anyone using the drawings will be invited to make a donation to REMAP, MEW's sponsored charity. Full details are with the drawings at www.model-engineer.co.uk/metalmaster

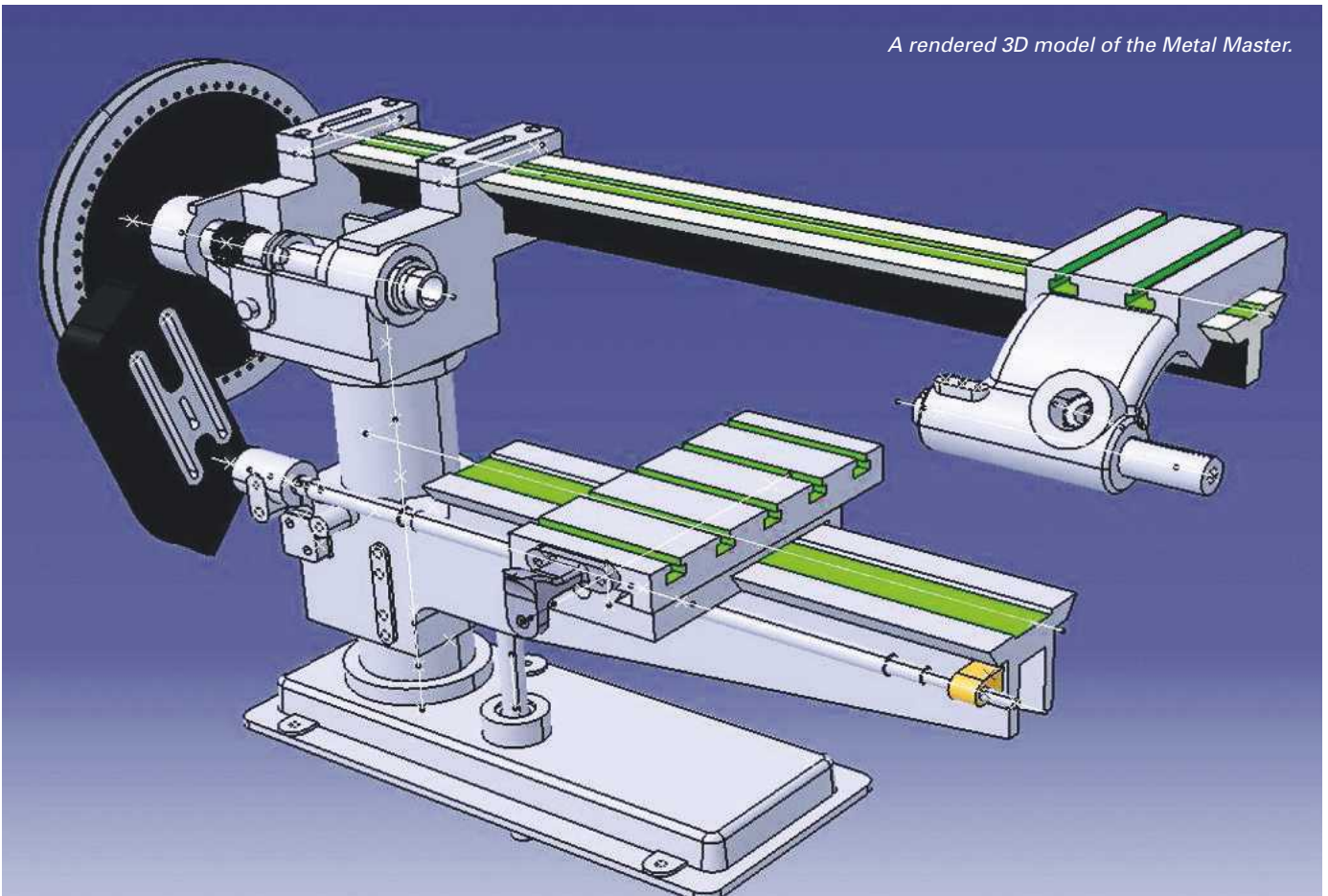
A member of the Metalmaster yahoo group re-created the core set of drawings as 2D DXF files and posted them for the group. Another member of the group

made expanded polystyrene patterns to enable a set of castings to be made by the lost foam process. Some of those images have been included online to assist with visualization. Another member of the group created the text files of David Urwick's notes and they are included also.

Metal Master unique features

Metal Master Machine Tool unique features identified by W. D. Urwick are listed below.

- 1) Vertical movement of the bed benefits all operations.
- 2) Machine will swing 8.00 inches between centres or 14.00 inches over bed with tailstock and auxiliary bed removed.
- 3) Back feed tailstock will pass right over saddle - no overhang.
- 4) Tailstock fitted with zero setting depth gauge.
- 5) Pulley / Flywheel / Hand wheel 11.00 inches diameter serves as a 60 hole dividing head with subdivisions to 360 degrees.
- 6) Large slotted work table 10 x 4.5 x 7.5 inches cross travel.
- 7) Large indexing dials (3 and 3.5 inch diameter) to cross slide and leadscrew.
- 8) In normal use a 4x4 tool post is used without top slide. No packing of tools is necessary.
- 9) Top slide for short tapers only.
- 10) Taper turning between centres for full travel of the saddle.
- 11) Hollow mandrel passes 3/4 inch stock bar.
- 12) No 3 morse taper nose accepts large collets.
- 13) A boring and facing head with auto feed can be used as in full scale horizontal boring practice.
- 14) An extra deep jawed machine vice can be used in view of the freedom of vertical movement and end mills, flycutters and slitting saws used as with a horizontal milling machine.
- 15) The machine can be used as a hand shaper for cutting keyways etc.
- 16) A special simple screwcutting system is used, providing a range of threads with elementary trains and a selection of metric thread to reasonable tolerance accuracy, also 19TPI.
- 17) The use of a single dog clutch on the mandrel makes it impossible to pick up the wrong thread.
- 18) The accuracy of parallel turning is under control of the operator - the bed is adjusted to 'zero taper' condition.
- 19) A dial test indicator (DTI) mounted on the auxiliary bed is, at all times, available to check and align work in the machine.
- 20) The entire machine can be readily dismantled into manageable pieces, put in the back of an estate car, and reassembled elsewhere ready for work, very quickly.



A rendered 3D model of the Metal Master.

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A Precision Machine Vice

Part 3



Michael Checkley shows how you can make a solid and practical tool that also looks good in the workshop.

Designing and building a vice gives the opportunity for many personalised features to be incorporated in the design including mounting features for different vice orientation; endstops; and a variety of custom vice jaws for clamping different shaped parts.

Clamp ring (fig. 8)

The clamp ring performs the duty of holding the leadscrew nut in place and does not require any great accuracy to perform its function.

Chuck some mild steel bar in the lathe. Face and turn the OD, ID as per the drawing. Add chamfers or just debur to remove sharp edges and part off to the correct width. The dimensions are not critical but follow the drawing to avoid any interference. Clamp the ring on to the bed of the milling machine elevated using washers to allow for drilling through the part. Centre the milling spindle on the centre of the clamp ring and drill the five clearance holes. Using the same hole centre location machine the slots to provide a recess for the socket head cap screws (photo 21). Finally mill a flat on one side of the clamp ring so it sits nice and flush with the moving jaw.

Support Plate (fig. 9)

The support plate resists any rotation of the moving jaw when clamping a workpiece. As the leadscrew is situated below the point at which the clamping force is applied there will always be a moment generated rotating the jaw.

All we need for the support plate to function properly is one smooth surface. Machine the plate to size leaving the thickness slightly oversize. Then, using the flycutter machine the thickness down to size (photo 22). The thickness isn't critical but a nice smooth surface helps the plate run smoothly against the top face of the T slot machined in the base.

Mark up the plate with its final dimensions and using the edge finder locate the mill spindle on to the edge of the plate. Using your measured dimension adjust the dimension from the hole to the edge to ensure the hole pattern is in the centre of the plate. Drill and counterbore the four holes as per the drawing (photo 23). Add chamfers or deburr all around the plate to remove the sharp edges.

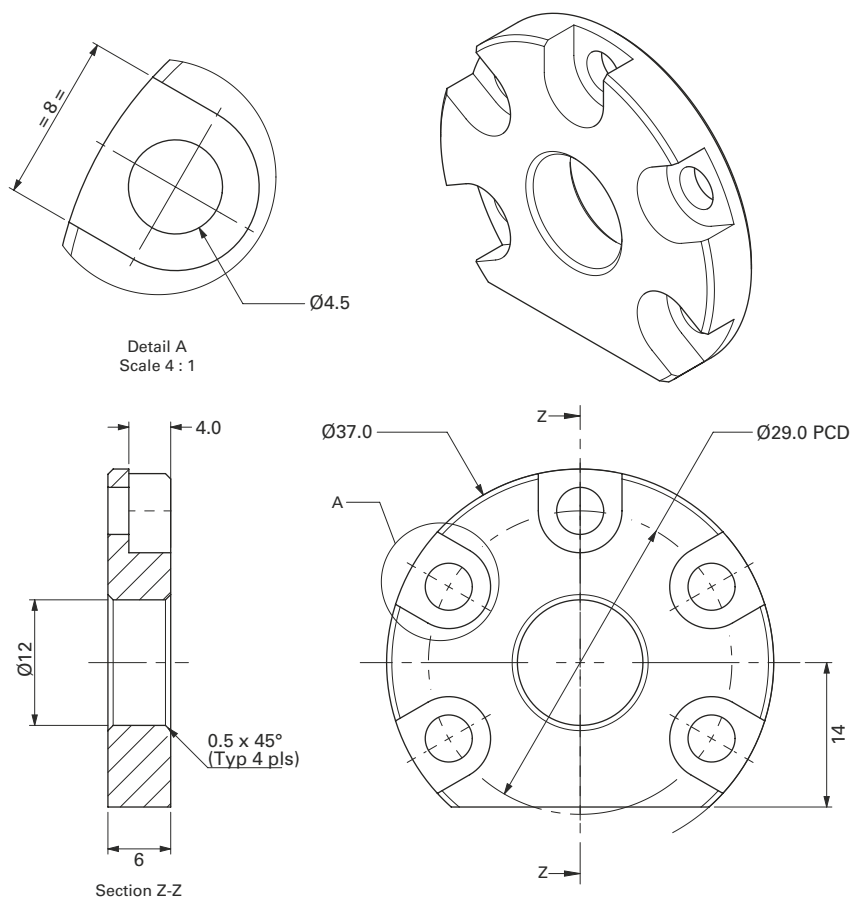
Vice Jaws (fig.10)

Making our own vice jaws provides a customizable feature of the vice for the clamping of different shaped workpieces. I decided to incorporate a V shaped

grooved in one of the jaws in both the horizontal and vertical direction for the clamping of round bar.

To improve the accuracy of the jaws I decided to use ground stock as this material is parallel and machined to overall size. All that is required is for the material to be cut to the desired length. The length isn't critical but it is desirable to have them both the same. Once cut to length measure the final size of the jaws and adjust the dimensions from the hole to the edge to get the two holes centre on the jaw (photo 24). Drill the holes as per the drawing and repeat the process for the second jaw.

Fig. 8



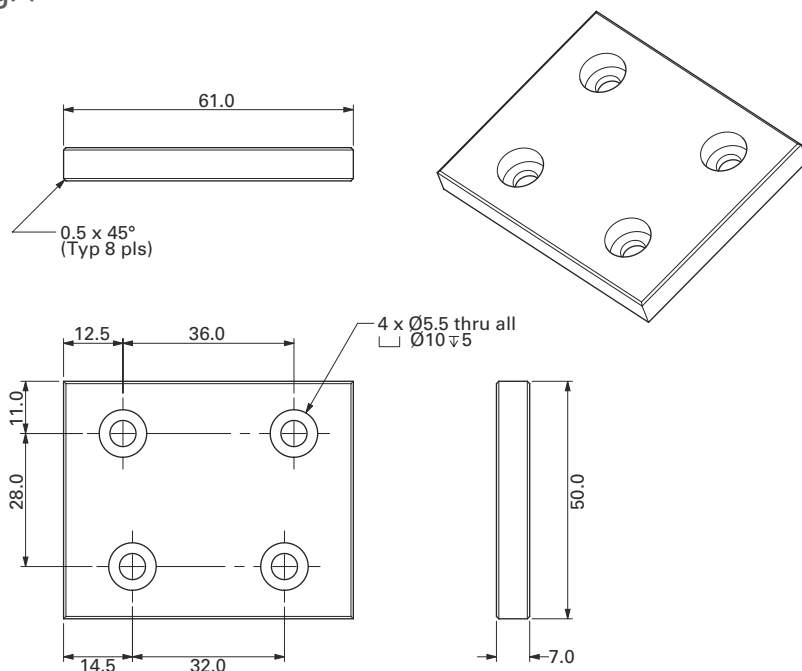


Milling the counterbore slots.



Machining the plate to the desired thickness.

Fig. 9



23



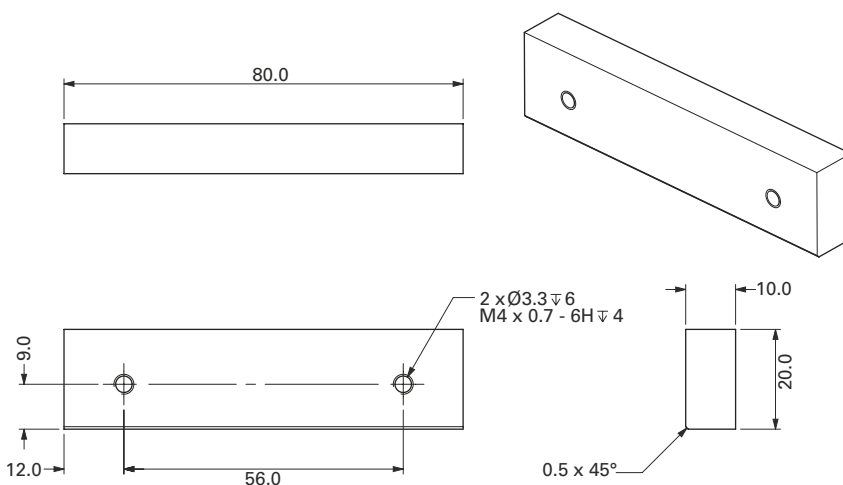
Drilling and counter-boring the holes.

24



Mark out the holes from the reference edges and drill the holes.

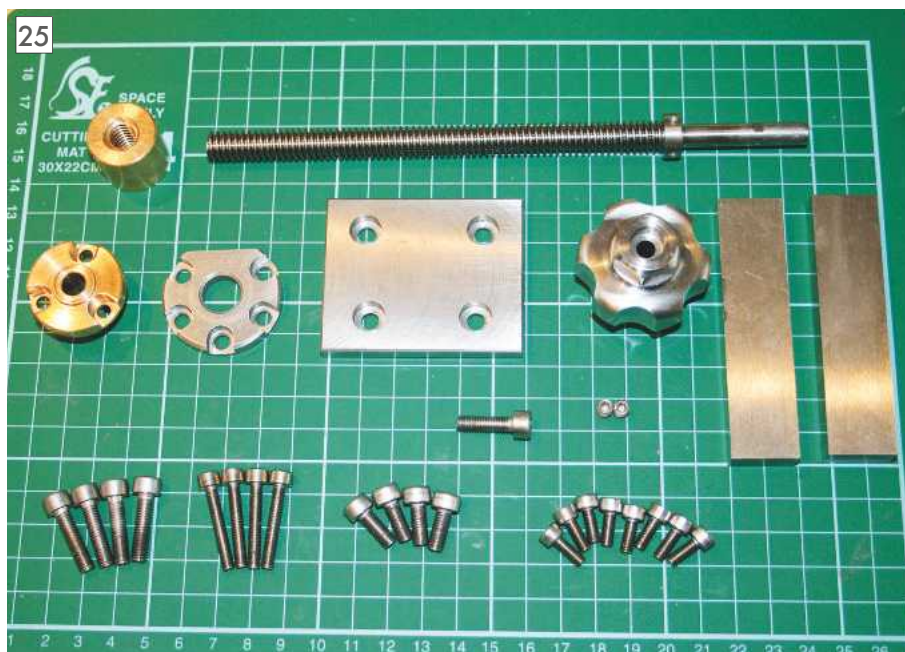
Fig. 10



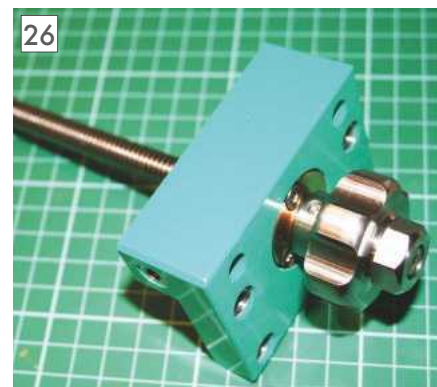
Vice assembly (fig. 11)

This is the stage where the parts are carefully aligned and shimmed to ensure smooth operation.

Bolt the support plate to the moving jaw and check how smoothly the moving jaw slides along the vice base. Mine was tight so I shimmed the support plate with a single layer of aluminium foil which allowed the jaw to move freely with no undesirable 'wobble'. Locate the leadscrew nut in to the moving jaw and secure in place using the clamp ring. At this stage tighten the screws finger tight. If there is any movement of the nut in the bore then a few operations of the vice will help the nut to find its best position and then the nut is clamped in place. Secure the collet to the leadscrew and wind the leadscrew in to the nut (photos 25 & 26).



The fixings and some small parts.



Leadscrew assembled in to fixed jaw.



Masked base sprayed in primer.

Secure the leadscrew bush in place within the fixed jaw and mount the fixed jaw on to the vice base securing with four M5 screws. Again, these screws should only be tightened finger tight as a few operations of the vice will align the parts.

Fit the finger grip knob and secure using the M5 screw and two M4 grub screws. Operate the vice a few times lubricating the sliding faces with slideway oil. Tighten all the fasteners.

Secure each jaw in place using two M4 screws. There are no features on the jaws to ensure they are sitting square so these will have to be 'clocked' for square every time they are removed and replaced. Alignment features such as dowels could be included in the design if one desired.

I decided to paint my vice as I feel it gives the vice a more finished and professional look but the vice could have stayed as bare metal. Emory cloth on a surface plate will quickly remove machining marks but can just as quickly round off edges and corners ruining (in my opinion) the finished look of a part. I would therefore recommend that any heavy emory cloth work is done before chamfers are added to achieve nice well defined corners.

Once happy with the surface finish of the machined parts I masked off all mating surfaces and internal surfaces and sprayed each part with an acid etch primer (photo 27).

Finishing the parts

How much effort is put in to this stage is entirely the choice of the builder as this will not affect the performance of the vice but will make the vice a more desirable tool to use and gives the vice a more professional look.

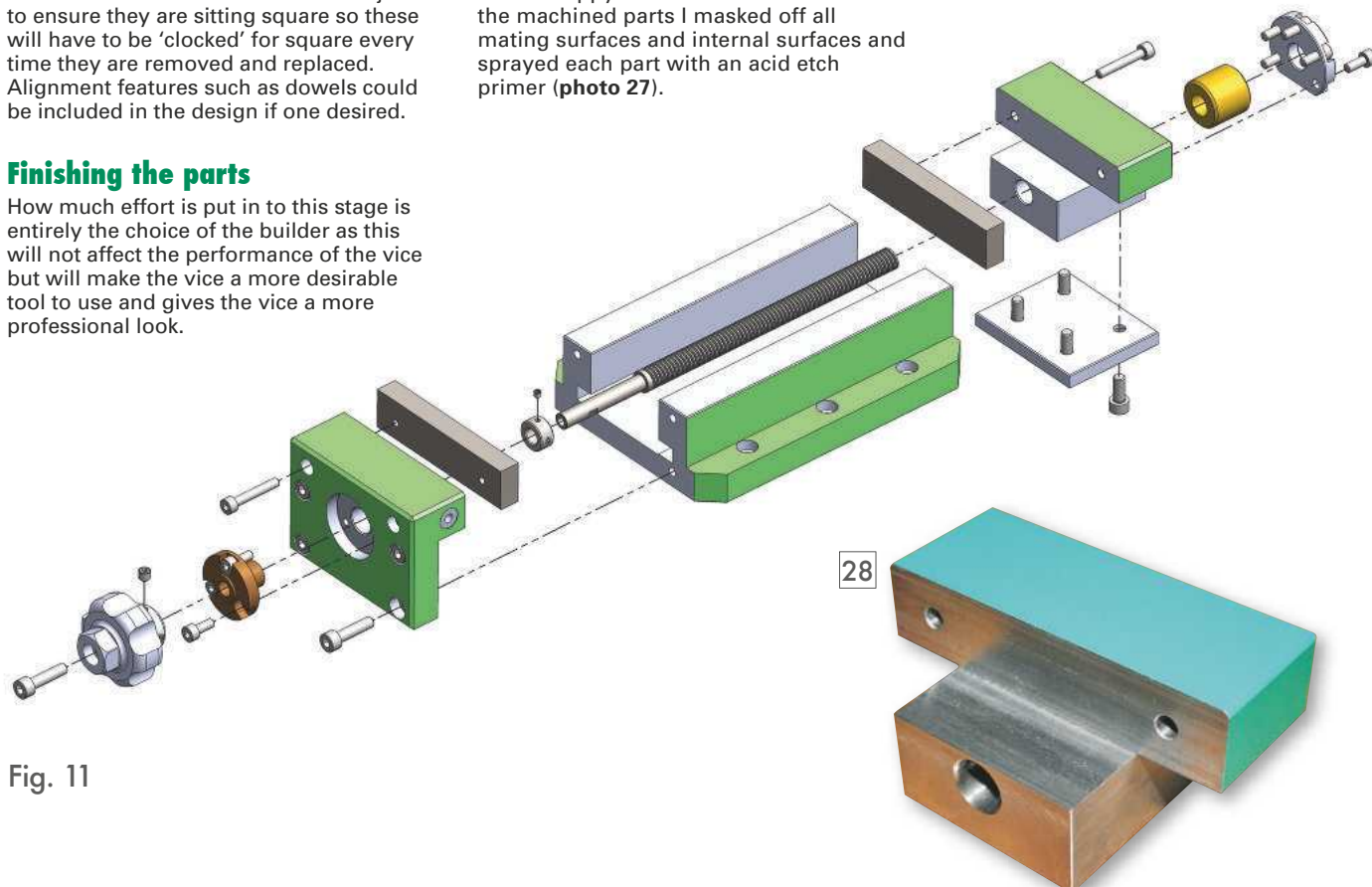
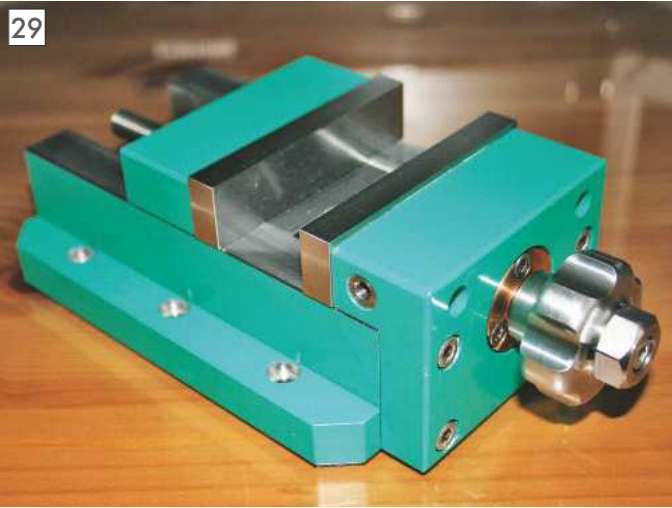


Fig. 11

Moving jaw with final green paint.

29



Finished components assembled.

Two coats of primer gave good coverage and a smooth surface. Following the primer I then gave three coats of topcoat, enamel based Plasticote (**photo 28**). I'm still undecided how resistant this paint is to cutting fluids so proceed with this paint at your own risk! It hasn't come off yet but I'm sure there are better paints out there

that would give a more lasting finish (**photo 29**).

Once assembled I decided to machine a step in the jaws for holding a low profile workpiece (**photo 30**). Clamp a parallel in the jaws to hold the moving jaw firmly in place and machined a 3mm x 3mm step in each jaw.

30



Milling steps in the jaws.

This vice design allows plenty of scope for customisation. For those that would benefit from new drawings with their features added then please feel free to email mikecheckley@yahoo.co.uk and I will do my best to provide updated drawings. ■

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One Man and his Lathe

Morgan Jones and his Hobbymat MD65



The Hobbymat MD65 was a bright yellow East German mini-lathe (specified as 65mm swing and 300mm between centres), sold in the late '80s until the Berlin Wall came down, and I bought mine new in August 1990 for £410. Like many Soviet bloc products, the detailing was less than perfect, but the machine is solid (45kg) and the fundamentals are good, putting many contemporary lathes to shame. My machine came in an expanded polystyrene box that fitted in a hatchback car boot, and was very well tooled as standard, including:

- 80mm three jaw self-centring chuck with standard and reverse jaws
- MT2 headstock dead centre
- MT1 tailstock live and dead centres
- 10mm Jacobs-type drill chuck
- Terrible tool post
- Twelve change wheels: 20, 30, 35, 40, 50, 55, 60, 65, 70, 75, 100
- Right angle plate
- Small vice to allow light milling
- Appropriate spanners, hex keys, and screwdriver
- Operating Instructions and Spare Parts List (48 page yellow booklet)
- Supplementary Notes by Peter Jones (12 page yellow booklet)

I bought the lathe because my main hobby interest is audio and the SME Series V pick-up arm had just appeared. However, the SME was £1200 (a lot now, let alone in 1990), so I figured that even if a lathe plus accessories reached £1000, that was still cheaper than the SME V, and I'd have a lathe left over at the end.



General view of lathe on kitchen chopping table, squeezed between boiler and fridge.



Hobbymat MD65 under bookshelf having underslung fluorescent lamp.

Installation

You need access to the change wheels and belts, so the headstock's folded steel cover needs room to swing fully open, and you need room at the right to operate the leadscrew's control wheel. The manual states 800 x 280mm, but these are lathe dimensions, not the space needed, and 1200 x 400mm is a realistic minimum. The lathe will inevitably be pushed up against a wall, and mine is in a dark corner, so I hung a small book shelf above the lathe and screwed a 2-foot fluorescent fitting to the underside of its lowest shelf (**photo 1**).

I replaced the fitting's choke ballast with a high frequency ballast to remove flicker, then added a shade to prevent direct sight of the tube. The original tube was replaced by an Osram L 18W965 from their Biolux range of tubes specifically designed for good colour rendering and often used for treating Seasonal Affective Disorder (SAD). They can be ordered from the distributors that supply electricians and the far superior light is well worth a little extra expense.

This local fluorescent light is excellent, but I wanted to be able to see what was happening when boring, so I drilled and tapped a pair of holes in the tail stock to fit a mains-powered LED spot lamp to the tail stock pointing roughly down the lathe's axis. The spot lamp is connected across the lathe's motor and its cable

passes through a pre-existing hole in the lathe bed to the power switch. Unlike the local fluorescent, I have mixed feelings about the spot lamp as it tends to foul fingers when tightening drills in the chuck. The light and lathe plug into a semi-permanent four outlet extension lead hung on the wall clear of the swarf zone and allow a vacuum cleaner to be easily plugged in.

As the lathe only weighs 45kg, it does not need a custom-built stand, and a solid table will do. My MD65 progressed through two other supports before settling on a second-hand kitchen chopping table (1200 x 500 x 900 WDH) that proved ideal for the task. The lathe's base casting has two mounting holes, but bolting to an imperfectly true bench risks twisting the bed, so I covered the table top with carpet tiles, sat the lathe on these and used the mounting holes as locators for a pair of brass pillars drilled into the table top. The carpet tiles have the secondary benefit of reducing noise, although I always wear ear muffs when using machine tools (**photo 2**).

Workholding

The head stock spindle has an MT2 taper to take a dead centre, and all other work holders are secured by three studs, either M5 or M6 onto an 80mm chuck flange (**photo 3**).



80mm flange with MT2 internal taper and adjacent motor.



Custom face plate interfaces between flange and four-jaw chuck – note the M6 nuts that secure the chuck in the small gap between flange and head stock.



Collet chuck holder is secured by three M6 socket screws.



Space is limited in the transmission compartment – the slow speed attachment can just be seen at the bottom rear.

Fitting the nuts and washers in the very limited space behind the flange is fiddly, but the advantage over a screw-on chuck is that reversing the lathe does not risk mis-registration when screw cutting, or worse, a chuck unscrewing and dropping off. I use an old pair of long-nosed electrician's pliers to locate and spin the nuts, then a spanner for final tightening.

The standard three-jaw chuck will get you started, but I bought a four-jaw independent chuck as well, requiring a custom faceplate to match it to the chuck flange. Custom face plates were readily available when the lathe was new, but you'd need to make your own now, so bear this in mind if offered a lathe without four-jaw chuck (photo 4).

Millhill Supplies offered a 17.5 x R2 DIN 6343 collet set and holder that covered 3-13mm in 0.5mm steps, and given the lathe's price, this was a substantial investment, but I needed to machine small parts precisely from both ends. They offered a cheaper version in 1mm steps, but not a separate set of the intermediate 0.5mm collets for later upgrade, so I bought the more complete set (photo 5).

Fitting the collet holder necessitates machining the lathe spindle to make it nearly an interference fit into the collet holder before securing with three M6 socket screws. If offered a lathe with this collet set, check the fit of the collet holder on the spindle. Given that the collets are

quite crude with only three slots and a very limited range of adjustment, a cheaper/better solution might be ER collets in a holder having an MT2 arbor and draw bar (the internal bore of the spindle is 12mm).

Essex Engineering offered a 96mm Czech face plate, but I've only used it once as it is awkward to use. The problem is that the face plate is only a little larger than the spinning flange, so the back of a work clamp is obscured by the flange, making life difficult when securing and adjusting work.

Millhill Supplies supplied a centre turning kit and some rather poor fixed three-point and travelling two-point steadies. (MEW issues 216 and 217 had a good two-part article by Alan Wain that described how to make a much better fixed steady.)

Guards

As originally supplied, the lathe had a smoked acrylic chuck guard hinged on a long pin that screws into the head stock. The first time you use an independent-jaw chuck you will shear the pin when the furthest protruding jaw strikes it. I bought a set of screw extractors to remove the remains of the sheared pin, but moved

house and lost the guard before using them. Similarly, a soft plastic sleeve slips onto the head stock to shroud the rear of the chuck and must be removed each time the chuck is changed. If the sleeve and chuck guard are still fitted, the lathe has probably not had much use!

Transmission

As standard, the lathe's 1/2 horse power single-phase 220VAC reversible motor has a two-step pulley, a belt to the spring-tensioned four-step aluminium intermediate pulley, and a second belt to the two-step phenolic tailstock pulley, giving speeds of 250, 500, 1000, and 2000 rpm. Speed is easily changed by simultaneously rotating and rolling a belt onto a smaller step, then rotating and rolling the other end to the larger step. I bought two spare belt sets when the lathe was new, but I'm still using the originals.

Screw cutting

Even 250 rpm is too fast for thread cutting. Essex Engineering supplied a speed kit that added 78 and 156 rpm by replacing the two-step motor pulley with a three-step version, and adding a second intermediate pulley and third belt to the rear of the machine. I don't do a lot of screw cutting, but the slow speed kit can be useful for boring, so I'm glad I fitted it (photo 6).

The plastic change wheels might not inspire confidence, but twenty years' light use suggests that they are fine provided that they are kept oiled yet clean – the motor tends to blow fine swarf into the gear cavity. One change wheel (W) is on the tail stock shaft and another (L) on the lead screw, with a pair of concentric intermediate wheels (Z₁, Z₂) on the banjo. Once the wheels are fitted and meshed, drive to the lead screw is controlled by a rather crude dog clutch.

The lathe has an M18 x 1 lead screw and a table on the head stock gives change wheels for particular thread pitches, but the genius who created the table delighted in replacing multiple change wheels when a single replacement would do, and missed some important threads. One day,

I needed a 0.9mm pitch thread, but the lathe claimed ignorance, so I spent some time with a spreadsheet and devised a more complete version, **table 1**.

Note that in the new table, the final change wheel (L) stays at 100 whenever possible, partly because changing it requires dog clutch disassembly, but also because leaving it at 100 enables sensible auto-feed cutting speeds.

Although British Association (BA) threads are specified in millimetres, and I found change wheel settings for them, few perfectly match the 0.9n pitch requirement (n = BA number). The lathe can also cut far more Imperial threads than claimed, mostly with <0.1% error.

The Hardware

The lathe's saddle and tail stock run on a 40mm ground steel D-bed supported at one end by the tail stock's aluminium casting and at the other by a substantial plate bolted to the base casting. My MD65 cuts a very slight taper rather than perfect cylinders and this minor (and seemingly uncorrectable) imperfection recently provoked a search for something bigger and better.

The saddle is permanently driven by the lead screw, with a control wheel at the far right of the lathe. The 1mm lead screw pitch allows the friction-locked dial to have major graduations of 0.1mm and minor of 0.025mm. A lead screw conventionally pulls the tool into the work, so the head stock end has a thrust ball race to reduce friction, and I added one to the other end. Because the lead screw is a right hand thread engaging in the saddle, clockwise rotation drives the thread into the saddle, and since the thread is fixed but the saddle moveable, the saddle moves towards the tail stock – the opposite of most machines. Surprisingly, accustoming yourself to this reverse operation doesn't take long, even when going backwards and forwards between machines, but it is a Hobbymat oddity.

The saddle has three screws on its back for adjusting play as it moves on the D-bed, but some play or tightness is inevitable – the solution is not quite as good as a dove tail slide plus gibs. The saddle draws a 280mm long coaxial sleeve along the lead screw, significantly reducing (although not eliminating) its swarf exposure (**photo 7**).

The cross-slide is driven by an M6 x 1 thread, so its control wheel dial has the same graduations as the saddle, but because the thread engages in the fixed saddle and the thread moves, conventional clockwise rotation drives the tool into the work.

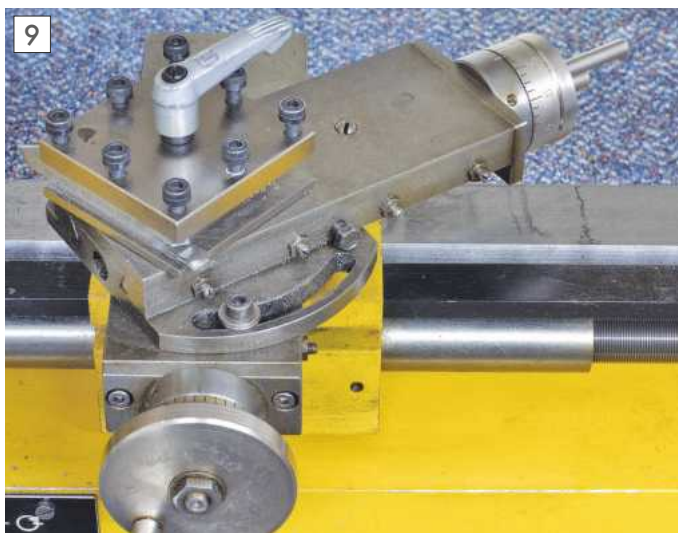
The dovetail cross-slide has a gib adjusted by four lockable grub screws, and careful adjustment allows smooth movement with negligible play. The cross-slide can be locked in position, but this is done by a cap head screw bearing on the gib and possibly distorting it, so I try not to use it (**photo 8**).

The top slide is one of the weak design points of the MD65, and is perhaps why the cut-down MD200 incarnation omits it.

RIGHT: The saddle is quite small. Note the top slide gib adjustments and replacement tool post. FAR RIGHT: With the top slide removed, the cross slide jib adjustments can be seen to the right, as can the 4mm pin that governs top slide rotation.

Table 1							
Pitch (mm)	W	Z1	Z2	L	ISO coarse	ISO fine	BA
0.2	30	60	40	100			
0.25	35	70	50	100			
0.282	55	65	20	60			12
0.3	30	60	60	100			
0.314	55	70	40	100			11
0.350	35	60	60	100	M1.6, M1.8		10
0.389	40	60	35	60			9
0.4	40	60	60	100	M2		
0.431	35	65	40	50			8
0.45	60	40	30	100	M2.2, M2.5		
0.477	35	55	75	100			7
0.5	50	60	60	100	M3		
0.531	65	70	20	35			6
0.55	55	60	60	100			
0.591	50	55	65	100			5
0.6	40	50	75	100	M3.5		
0.65	65	60	60	100			
0.656	35	40	75	100			4
0.7	70	60	60	100	M4		
0.729	35	60	50	40			3
0.75	75	60	60	100	M4.5		
0.8	40	60	60	50	M5		
0.808	35	40	60	65			2
0.9	60	40	60	100			1
1	60	30	50	100	M6	M8	0
1.1	55	60	60	50			
1.2	60	75	60	40			
1.25	50	60	60	40	M8	M10, M12	
1.3	65	60	60	50			
1.4	70	60	60	50			
1.5	75	60	60	50	M10	M16, M20	
1.6	40	50	70	35			
1.75	70	60	60	40	M12		
1.8	60	40	60	50			
2	70	60	60	35	M14, M16	M24, M30	
2.1	60	50	70	40			
2.2	55	50	70	35			
2.4	60	50	70	35			
2.5	75	60	60	30	M18, M20, M22		
2.6	65	50	70	35			
2.8	60	50	70	30			
3	75	50	60	30	M24, M27	M36	





The problem is that a 65mm swing doesn't really leave enough room between the top of the tool tip to the lathe bed for all the intervening parts. Thus the top slide is fastened directly to the cross slide by four M5 screws, and its centre of rotation is defined by a 4mm pin, with the four screws passing through a pair of cast arcs. Rotation is limited to about ± 50 degrees, and even 45 degrees requires removing two screws, leaving only two screws to secure the top slide (**photo 9**).

Like the cross slide, the top slide is driven by an M6 x 1 thread, but the control wheel is smaller and has two handles, making it awkward to return quickly to the starting position after a cut has been made. If the handles were screwed in as all the others are, removing one wouldn't be a problem, but they're pressed in, so removal without damage would be difficult.

The dove tail top slide has gib adjustment and locking, but because it needs to be thin, it is easily distorted by the tool post, tightening movement at some slide points. Unless perfectly adjusted and lubricated, my top slide has a tendency to cut slightly wavy lines.

Tool post

The standard tool post is so terrible that I binned it within a week of the new lathe's arrival, so I can't show you how awful it is. Suffice to say that it was a cylinder with an overhanging top lip having vertical hex screws that tightened the tool directly onto the top slide (thus distorting it).

Essex Engineering made an excellent 4-way rotating tool post. Not only does the 4-way post allow adjustment of tool angle without compromising how tightly the tool is held, but the tool post's lower flange reduces distortion of the top slide. The penalty of the rotating tool post is that the cutting tip must be <6mm from the bottom of the tool, tending to enforce 6mm tools or smaller.

There isn't enough room for a quick-change tool post, so you have to get used to shimming tools to centre height, and this is the final weak design point.

Tailstock

The tailstock quill has an MT1 taper and the supplied 10mm chuck had a key that didn't fit properly. I quickly bought

a 12mm chuck with correctly fitting key, but ARCeurotrade.co.uk stock a very nice 6mm chuck and JT1/MT1 arbor that is much better for most work and thoroughly recommended (**photo 10**).

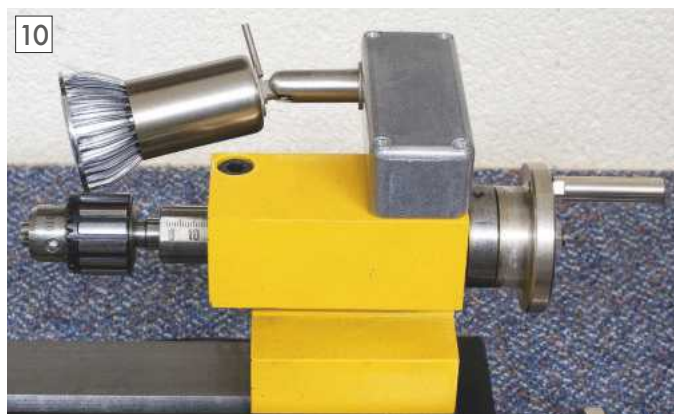
The cast iron tail stock is bored to slide on the D-bed and locked/adjusted by two screws. Tightening the end screw opens the slot, loosening the bore onto the bed and allowing freer movement, whereas tightening the centre screw closes the slot to lock the tail stock in place. Correct adjustment of both screws is essential. The end screw should be preset, and only the centre screw used in operation – I leave a long arm 6mm hex key in this screw.

Quill movement is achieved by an M8 x 1.25 right hand thread, and because the thread is stationary but its nut movable, clockwise rotation pulls a drill away from the work – just like the lead screw. This reverse operation isn't a problem, but because the thread is 1.25mm pitch, the control wheel is ungraduated, although the quill has 1mm graduations. When I really need to, I print a graduated paper tape and stick it round the control wheel. A better solution would fit a yoke to the quill plus a digital gauge akin to those fitted to pillar drills. Frankly, the problem occurs so rarely that an occasional printed stick-on gauge suffices for me.

Using the Machine

The MD65 is a little lathe. It isn't big and it isn't heavy, so it flexes if you take a heavy cut. Most of the time this is manageable, but two operations cause trouble. Parting is notorious for the tool digging in and precipitating disaster; parting on the MD65 is so nerve-wracking that I use a hacksaw.

Milling takes a discontinuous cut as each cutting edge comes round and chips at the work. I don't care what the manual says or



The tail post with LED spot lamp and 6mm chuck – note the graduated quill but ungraduated control wheel.

The top slide has been rotated to 45 degrees but can be only secured by two screws...

what the existence of the BFE65 milling head implies, the MD65's light cross slide on D-bed simply isn't suited. I once used a slot saw in the MD65 to cut the slots in an aluminium collet I was making and keeping vibration to an acceptable level made the work very slow. A few months later I bought the proper tool for the job; a small mill.

When my eye is in, I can machine to within a quarter thou (that's <0.01mm for the metric amongst you), and that was good enough to make the pick-up arm which was finished in 1993 and has been in use ever since (**photo 11**).

Friction in pick-up arms is crucial, so the arm is a unipivot (PTFE dimple resting on ball point pen tip), which means that balancing on that single point simultaneously allows tilt and rotation (and twist, but we don't talk about that). Although simple to make, unipivots are notoriously difficult to align, so my chief design aim was to make as many adjustments independent of one another as possible, but that made some of the hidden machining quite tricky.

Electronics engineers are traditionally poor at metalwork, and mine isn't exhibition quality, but I'm improving and it's a rare week that doesn't include machining.

Overall impressions

The Hobbymat MD65 is the ideal first lathe. It is good enough to do quite serious work, but not fashionable enough to be punitively expensive. It is light enough to be used upstairs and can be carried (at a pinch) by one person. It has taken me twenty years to outgrow the MD65, so even though I now have a three-phase Colchester Bantam that weighs almost ten times as much and is an altogether better machine, I'll be keeping the MD65 for small work. ■



The reason the Hobbymat was bought – the author's pick-up arm in action.

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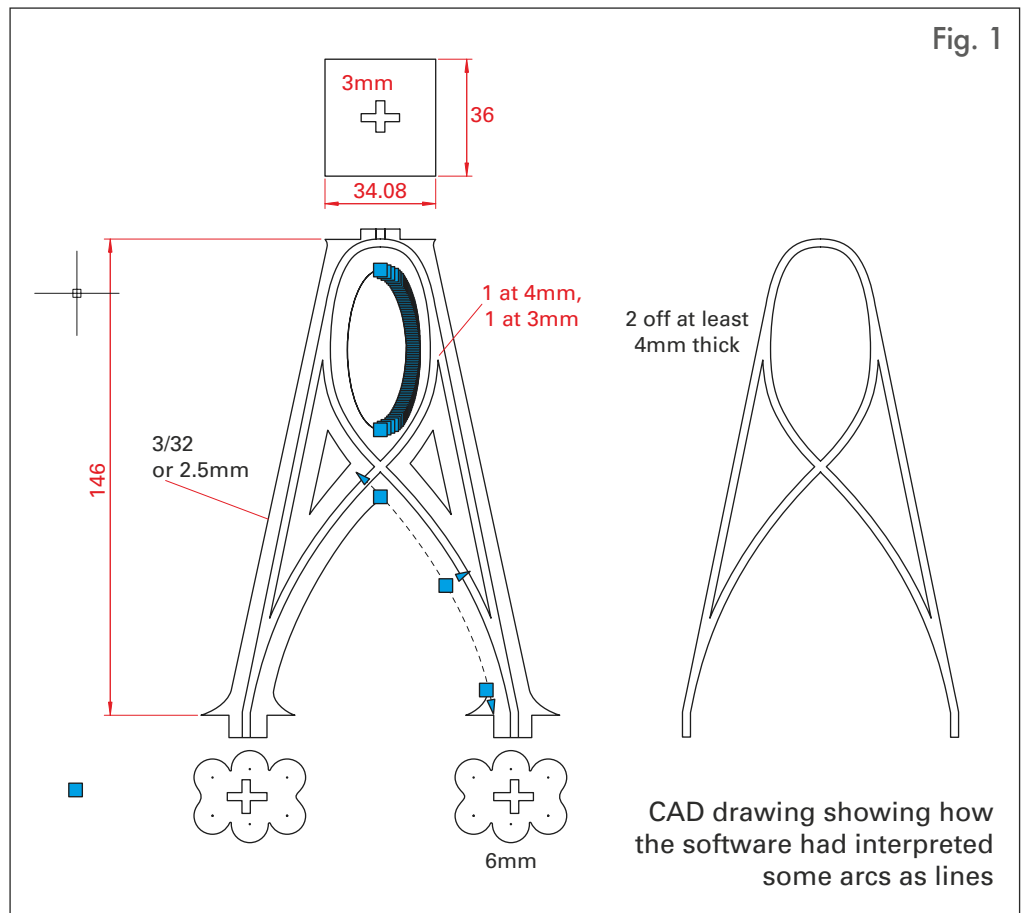


Producing CAD files for laser and water jet cutting



Malcom High offers some advice to readers looking to have parts machine cut to their own designs.

Neil Wyatt asked me to produce some laser cut parts for a stand he had to make for a stationary engine. It raised the question as to how this could be done and what form of drawing I would require. Having been producing parts now for nearly a decade I have been given this information in many different formats. Written description, fag packet sketch, pencil drawing and CAD files just to mention a few. It was decided a short article on my experiences might be useful.



A written description or a part to copy are not methods to be recommended. The latter can now be done very accurately by a machine which scans the part with a laser and then produces a drawing. The former can only be used if an existing CAD file has to be changed slightly. I have one particular customer who will say 'Scale up part 12036 by a factor of 1.43, then reduce the height by 4mm'. This is fine for that part but it is only possible because the original was to his design. Normally any form of description is a non-starter.

Fag packet sketches are not usually sufficient unless it is a very simple part and the dimensions are all there. Better are paper drawings but even then, as we are all aware, it is quite common for dimensions to be missing. This is not too bad if it is cosmetic but when the main radius is missing on an expansion link it can create a few scratched heads. I have often been

asked if it is possible to scan in the drawings. Well no, not really. The laser is accurate to three thousandths of an inch; I doubt the drawing is that accurate. Again if it is a cosmetic piece it may be possible to use a scanner as we shall see later.

Normally I would redraw the part in CAD, inputting the dimensions in Imperial or Metric. The final drawing has to be drawing exchange format (dxf) and on a metric template. Unfortunately if you use an imperial template your five inch gauge Springbok comes back from cutting in N gauge! If anyone would like to make a B1 in N gauge I can do them a deal on a set of frames.

Back to Neil, he sent me an Adobe Acrobat file (pdf format) with the drawing on, which I assume had been scanned in. There is a free package you can download called Aide pdf to dxf converter. I had used it once before but not with any great success. The parts Neil required cutting were not critical,

the only important dimension was the overall height and this could be sorted out later. After running the pdf file through the converter the first thing to note was that the height was wrong, it was too short. This was due to scaling and easily corrected. The CAD package I use will rescale by either a factor or to a reference length. So it was just a case of inputting the height required and the computer did the rest. The top was not quite parallel with the base. This was corrected by putting in a new line and joining it up to the curves. The drawings are shown in **fig. 1**. Note that the software has interpreted the lower arc correctly but the top one is over 100 short lines.

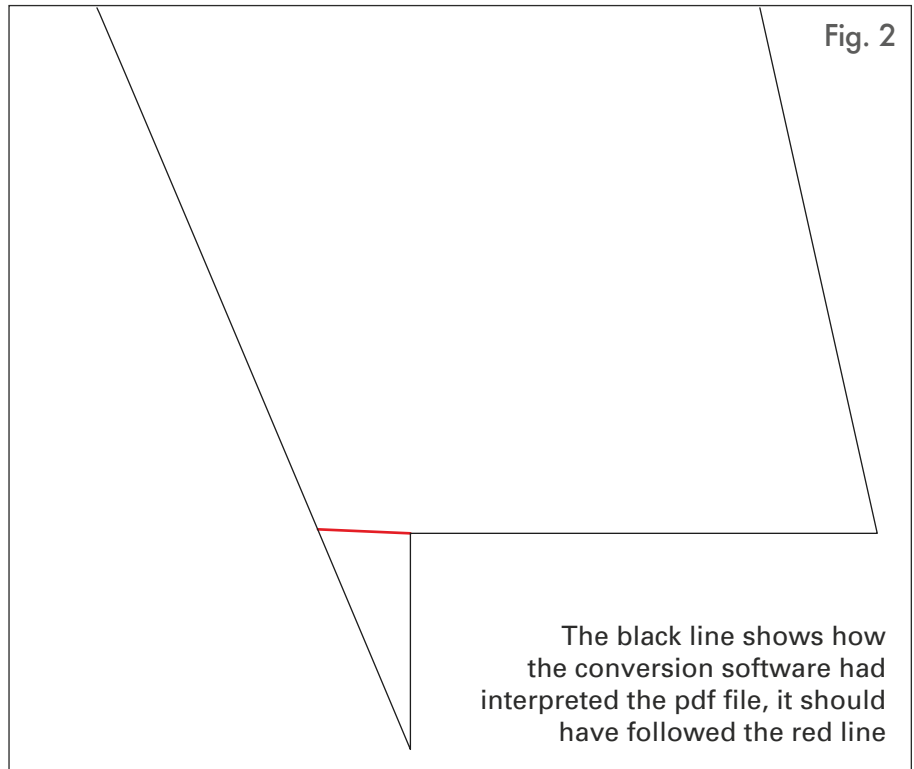
It is essential that the cutting line is one single continuous line, with no gaps and all on the same plane. The test is to convert it into a polyline and it is at this stage that many of the CAD files I receive fail. It has to be a single line. It is extremely easy when drawing something

fairly complex to get two lines on top of each other. The post processor which converts the dxf file into G code does not know which line to follow, gets confused and gives up in disgust. Some of the latest software can overcome this, but it is best to present the cutter with a perfect file.

Gaps are normally down to poor drawing practice. All CAD packages will have snap commands where the cursor will lock onto another line or curve. The chamfer command can be set to zero and then used to join two lines. The fillet command is extremely useful in ensuring lines and curves join. Another method is to use the tangent command rather than just snapping onto the curve.

Normally when using a 2D package the lines will all be on the same plane. It does not have to be Z=0, any plane will do. With 3D packages now becoming more popular the problem of non-coplanar lines has become more prevalent. What appears to happen is that on exporting or saving the drawing as a dxf the software cannot decide whether to use the top of the plate or the bottom of the plate as its line. So sometimes it uses the top and sometimes the bottom. What it means is the lines will not join up. The first time I came across this problem I could not understand what was happening. The cure is to change the properties of the lines such that they are all on the same plane.

To get back to Neil's stand, it was noticeable that on the CAD file the curves were actually many short lines, the conversion software had not realised the lines were arcs. Zooming in on the lines revealed that they had a saw tooth appearance. This was to be expected really but since the height of the teeth was only a few microns it would not be noticeable on the final product which would need to be draw filed anyway. Worse were the two lines that doubled back on themselves - this would have created a shallow cut in the edge as seen in **fig. 2**. These were removed by deleting the offending lines and drawing in new ones. The only part that required redrawing was the base. This was no



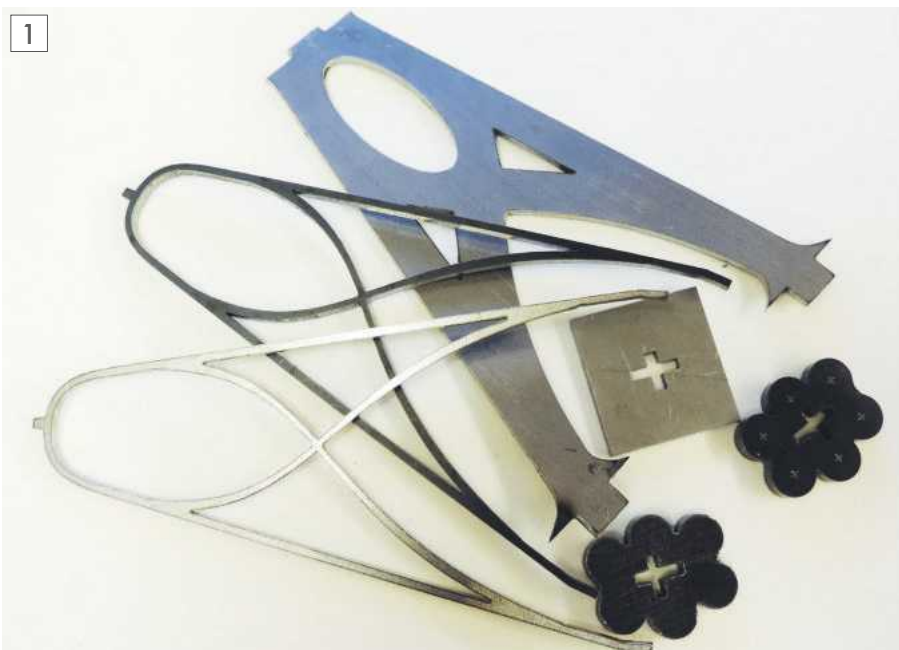
longer symmetrical and the lines did not join up. A simple part to do was the top which was the only part not on the drawing. Finally the lines were all joined up as a polyline.

To assist in the assembly operation the parts were tabbed and slotted. There is no hard and fast rule about this, if it looks right it probably is. The bases and top had slots to accept the central plate and cut outs for the trim to go into. The tabs were left too long so they could be damaged on assembly if the parts were to be silver soldered. In this way they would not come apart at 650 degrees centigrade. It would have been possible to TIG weld the ends over if preferred.

With the files completed it was a case of e-mailing them with a number of others to

the laser cutters. I often get asked if I do the cutting myself. No, I subcontract that. Machines can cost one million pounds and need a large building to house them. Nitrogen makers, gas tanks, stock room and plenty of highly trained operatives are also required, not something I would even consider. The expensive part is getting the file ready for cutting. In the case of Neil's stand that would be far more expensive than the actual parts.

This was a fairly simple job compared with many I undertake. However it was interesting in that the conversion software was very successful in producing the CAD file. The parts, **photo 1**, took the place of a casting which would have been far more expensive to have made, and yet the final stand, **photo 2**, looks very convincing. ■



The laser cut parts as supplied.



The stand after fettling and assembly by Neil.

Workshop Tools at the Model Engineer Exhibition



MEW Editor, Neil Wyatt, journeyed down from the midlands to enjoy his first visit to the Model Engineer Exhibition at Sandown in December.

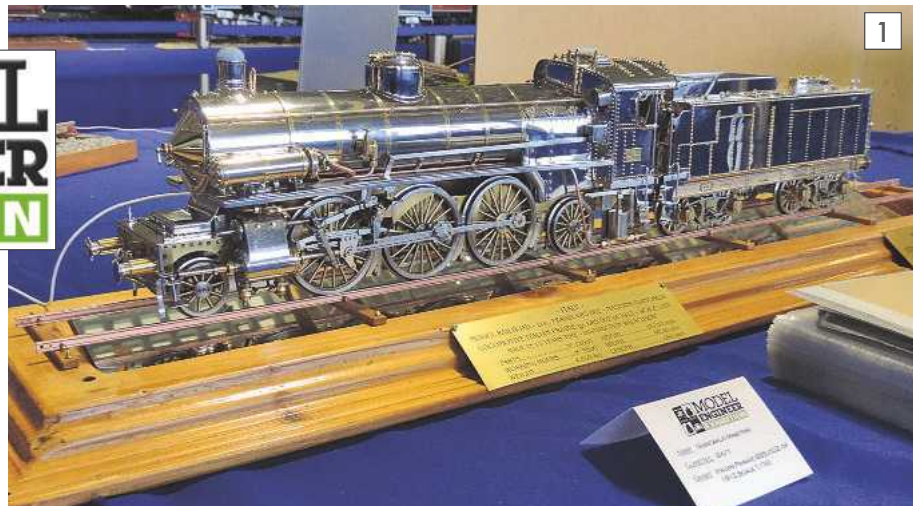


As I live well north of Brum, I was delighted that the role of editor gave me the excuse to spend two days at the Model Engineer Exhibition. I found almost as many new things on my second day as the first, and still didn't get to see as much of exhibits like the Stirling Engine Society and the full size traction engines as I had wished. My focus was naturally on workshop tooling and so I'd like to pass on some of the flavour of the exhibition to readers.

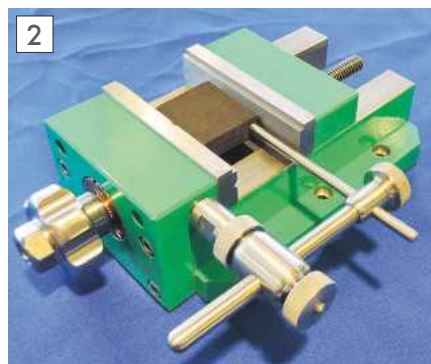
Competition and Loan Entries

The competition entries this year were outstanding (**photo 1**) – everyone agreed it was possibly one of the best ever selections of entries. I won't spoil the write ups to be featured in Model Engineer, I'll just say it took the best part of an hour for all the prizes to be distributed! Instead I'll just mention some of the tooling in the loan and competition classes. Nor will I describe the huge host of locos, boats, steam engines, trams and other products of busy workshops. My apologies for failing to note down every entrant's name.

I was pleased to be able to bring along Mike Checkley's machine vice (**photo 2**), which he was able to collect on the Sunday. I have persuaded Mike to write up the flexible stop, which he uses to facilitate setting up for CNC machining. Carefully secured in a glass jar, Neil Read exhibited an 'engineer's emergency



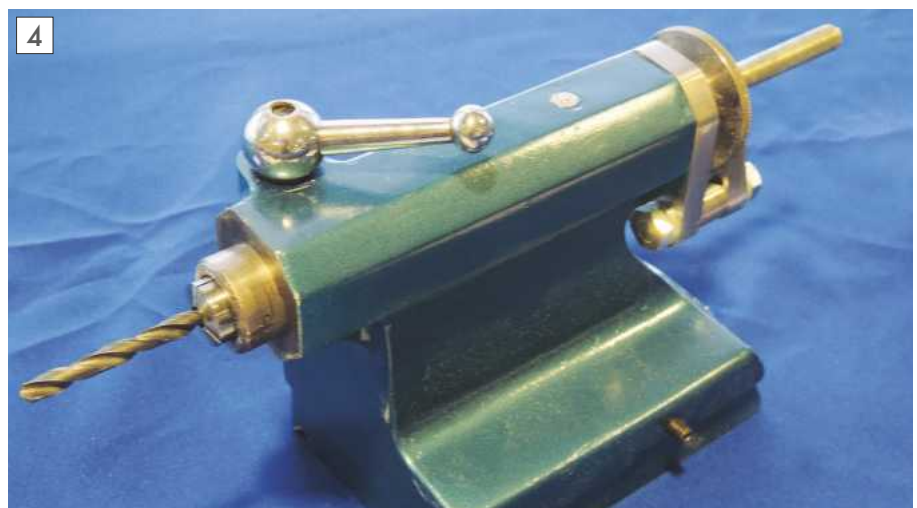
Giancarlo Mastrini's Italian Prairie locomotive.



Mike Checkley's device, as featured in this issue.

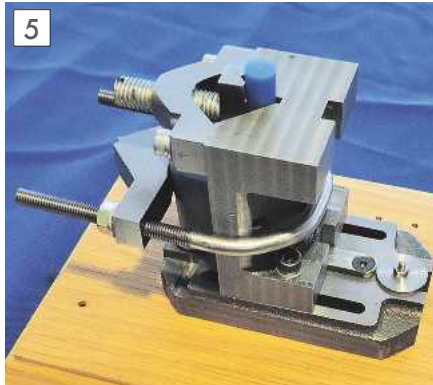


An engineer's emergency toolkit.



Collet tailstock.

toolkit' (photo 3), which had as many functions as a Swiss army knife, including some fine, if small, calipers. Other handy examples of workshop tooling included a collet tailstock (photo 4) and a 'keats' angle plate from a Hemingway kit (photo 5). One unusual and impressive display was a collection of lost-wax patterns for a rotary engine, accompanied by a video of the engine in action (photo 6).



'Keats' angle plate.



Rotary engine patterns.



A spiral dividing head by Ivan Law.



Nick Farr restored this pillar drill.



Nick's oil can to Mogen Kilde's design.



Trident Mill modified by Ian Strickland.



This is Ian's R&B engine.

Chief Judge Ivan Law was obviously reticent about entering the competition, but he did bring along a fascinating spiral dividing head (photo 7), like an ordinary one with another layer of complexity added! Ivan expressed how keen he is to

see more tools entered into competition, stressing that tools should be well made with a functional and appropriate finish – they don't need to be silver plated or have every visible surface hand-scraped to win an award.

Those who enjoy the reprints of old plans from MEW at www.model-engineer.co.uk will recognise the name of Nick Farr, who took on the mammoth task of scanning them all. Nick brought along his impressive restoration and update of an old sensitive drilling machine (photo 8), which I hope he will also write up for us, together with his interpretation of Mogen Kilde's neat little oilcan (photo 9). Mogen's design was published in a recent issue of MEW, I'm sure I caught more than one visitor using this beautifully polished fabrication as a mirror!

From the tiny, to the huge. Ian Strickland's wonderful R&B engine is currently featured in MEW, to make it he had to add a vertical milling head to his Trident horizontal mill (photos 10 and 11). It's now a very flexible and impressive addition to his workshop.



The East Surrey 16mm locomotive group.



Rose Engine on the SOT stand.



The rose engine's cams and micro-adjustment.



An ornamental turning lathe with tympen chuck.



Spiral milling on the Ickenham stand.



A tapping tool from Surrey.

Club Stands

The displays put on by the various model engineering clubs were really diverse, and we also had several operating (small gauge) railways, with three of them in live steam (**photo 12**). For the tool fan, a particular attraction was the Society of Ornamental Turner's display. They had this wonderful rose engine by Birmingham manufacturer, Plants of Harborne (**photo 13**). The diversity of cams (**photo 14**) was mind boggling, as were the many different slides and functions of the ornamental turning lathe that accompanied it (**photo 15**).

Other club stands focused mainly on models, but there were several interesting tooling exhibits on display. The Ickenham club had a display explaining the intricacies of spiral milling, including several accessories (**photo 16**), whilst the Surrey society display included a compact tapping tool (**photo 17**).

Trade Stands

Although there were still plenty of opportunities to empty your pockets, the trade stands were missing a few familiar faces this year. Nonetheless, Myford exhibited both a new Connoisseur (photo 18) and a beautifully refurbished ML7 which featured newly tooled, and British made, sensitive drilling and capstan tailstock attachments (photo 19). Variable frequency drive conversions are becoming increasingly popular, and Transwave were on hand offering much valuable advice (photo 20). Other trade stands offered a wide range of small and large tool, fixings and materials (from tiny short ends of brass to huge lumps of aluminium!) As well as the rotary tables, cutters and chucks there were some other unusual items (photo 21). There were some fine second hand machines, not least a couple of shapers. I treated myself to a little-used Osborn collet chuck at a very good price. Another really nice little item I will leave un-named, though I'm sure many readers will instantly recognise it (photo 22).

To be continued...



The Myford stand.



The refurbished ML7 with accessories.



Transwave and their range of motor solutions.



A swarf rake?



Can you guess what this is?

Scribe a line

YOUR CHANCE TO TALK TO US!

Drop us a line and share your advice, questions and opinions with other readers.

Metal Minds

Dear Neil, I very much enjoyed reading Murray Eddington's article 'From Mind to Metal' in MEW 221 and his explorations and findings as regards CAD drawing programs, 3D printing and machining.

In the article he mentioned that he designed and made a Spindle nose adaptor which allows D1-3 items/chucks to be held on a rotary table. I have been mulling over building one of these for ages but haven't got round to it. I wonder if Murray would consider doing an article on his design? There must be many others who also require such a device.

Peter Darveniza, Ballarat, Australia

Rust Removal (1)

Dear Neil, Readers may be interested to know that citric acid may be available relatively cheaply at a Home Brewing shop - £1.20 for 100 grams at my local one in Plymouth, and cheaper still in bulk. It is used for correcting the acidity of a duff batch of wine.

John Chapman

Rust Removal (2)

Dear Neil, You ran an article on rust removal by Robin Muir. Citric acid crystals are easily available in 'white sugar' form from home brewing stores and online. I used it a lot as we live in a very hard water area and it's also good for descaling kettles. It seems to work on all metals and especially on brass. I normally mix it in hot water adding crystals until the solution is saturated and a few crystals lie undissolved on the bottom.

It works better if the solution is kept warm. We have a central heating boiler in the kitchen and an overnight soak is usually sufficient. One last thing - if you're de-rusting steel don't get it on your hands as the smell will linger for sometime!

Martin Akehurst, Henley-on-Thames



Choice of Motor?

Dear Neil, I bought an Arrand Milling Spindle years ago intending to use it on my Super 7 cross slide. A job which involves drilling screw holes in a face plate for a woodworking lathe has come up, but I'm at a loss on how to power the Spindle. I haven't room in my workshop for an overhead pulley system and fixing an electric motor to the cross slide seems the better option. The trouble is I can't find a motor that is small enough and able at the same time to provide sufficient power to drive the Spindle. A 1/8 HP motor would probably suit but the ones on sale are too bulky. Can any reader suggest a solution?

Neil Macnaughtan, Edinburgh



Eric Payn's Essex Super Six Pacemaker.

Car Thermometer (1)

Dear Neil, I got my latest copy of *Model Engineers Workshop* no 223 on Saturday last, I was reading the scribe a line section re the vintage vehicle owned by Eric Payn of Jersey.

I think that the coloured fluid he describes is Alcohol, i.e. similar to the red stuff in a clinical thermometer. In the late 1960s when I passed my driving test my first car was a 948 cc Triumph Herald saloon, and I wanted to fit a temperature gauge to it. As it didn't have any plug for an electrical one I fitted a similar device which tapped into the top coolant hose.

It is vital on a car of this age that the cooling system is kept in tip top condition as without a water pump it relies on thermo-syphon action where the hot water rises to the top of the radiator and gets

cooled by the blast of air as the car travels, this was also common on pre and post war Ford cars.

There is a company advertising in *Practical Classics* that may be able to help Mr Payn. They are Speedy Cables (London) Ltd. Abercave Swansea SA9 1SQ. telephone 01639 732300. www.speedycables.com.

If he contacts them they may well be able to help him or if not they may know of somebody who is capable of both repairing and recalibrating this instrument. I am of course putting in the usual disclaimer not having used this firm but being a regular reader of this and other contemporary classic car magazines.

Hopefully this will be of some help to Eric.

J.E.Kirby, Stoke Newington

Car Thermometer (2)

Dear Neil, Regarding Eric Payn of Jersey's query about repairing a temperature gauge, I had a similar task once but with a diaphragm instead of a gauge. This is the method that I used:

- Clean out the temperature bulb
- Check that the capillary tube is clear
- Anneal the capillary tube
- Hard solder the sensor bulb to the capillary tube.

The Red liquid being an unknown, could I suggest either car brake fluid or automatic gearbox oil? Fill a small container with fluid, and put the open end of the capillary tube under the fluid surface. Then with the sensor bulb held vertically, capillary tube at the top, gently heat the bulb until air bubbles stop coming out of the end of the capillary tube. Allow the bulb to cool, this will draw liquid into the bulb. Repeat the process until no more air bubbles emerge.

Now to the tricky bit, soft solder the capillary tube to the gauge. Use soft solder as you may have to unsolder several times to set the liquid level. The calibration would entail immersing the bulb in water heated to the normal operating temperature of the car engine.

All the above is a tedious process but should work.

Tony Stark, Newport, Gwent

Tired of Waiting

Dear Neil, I hope all is well in the UK and that the winter is not treating you too badly. Congratulations to all on the 25th anniversary.

I just wanted to tell you that we have had a 4 month long postal strike in South Africa which was only resolved about 10 days ago so there is a huge backlog of mail, somewhere, and amongst those piles are my issue of *MEW*. The last one I

Relay Query

Dear Sir, I am going to install a 'Power Axis Motion' as described by David Reece in issue 214 of *Model Engineers Workshop*.

Would somebody please advise me as to what relays were used or to use.

H Cormick

received was issue 218. It seems that I have 6 issues missing!

I really do hope that these missing ones will arrive.

All the very best for the festive season and keep up the good work.

**Malcolm Cunnington,
Johannesburg,
South Africa**

We would love to hear your comments, questions and feedback about MEW

Write to The Editor, Neil Wyatt, Model Engineers' Workshop, MyTimeMedia Ltd., Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF. Alternatively, email: neil.wyatt@mytimemedia.com

Book Review

Making Scale Models

by Mark Friend

ISBN 978 1 84797 770 0

Published by The Crowood Press

This book is not what I expected it to be, and I must admit I thought twice before including a short review here.

The scale models in the book are a tree, a chair, a room and a human figure – and somewhat incongruously – a colourful exploding star, which, along with a plain cube, is an exercise in technique rather than anything else. The audience for this book are raw beginners, and the subject is scene setting – from 'doll's houses and or [a] model railway landscape' to 'a small piece of sculpture'. The raw materials are largely card and other 'craft' media, such as clay. It's not a book about engineering.

Mark friend's approach to models is not a precise 'rivet counter' one, it is not even that of the architectural modeller. Rather, his models are impressionistic, conveying atmosphere rather than claiming to be exact replicas. He is up front that this book is about where craft and art merge.

And that's why I'm writing this short review. I'm struck by his simple model of a suited male figure. Accurately proportioned, but lacking detail, it still manages to convey a sense of action and



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even apprehension. Many engineering models would benefit hugely from a 'diorama' type setting, and while it is possible to create accurate models of workshops and engine houses, the figures we see with even the finest models rarely have more than the appearance of dolls, just standing as decorations rather than really being part of the scene.

My thought is that figures, and other elements of the setting of models produced along the lines described in this book, could well be an effective way of presenting some engineering models. Appearing engaged with the subject of the diorama, but not competing with it in terms of detail they could bring real life into the scene.

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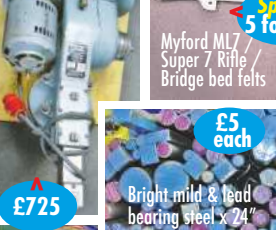
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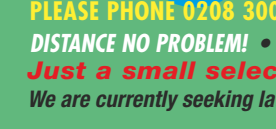
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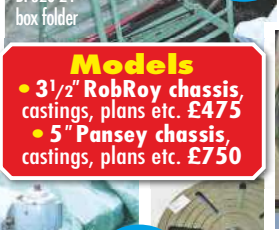
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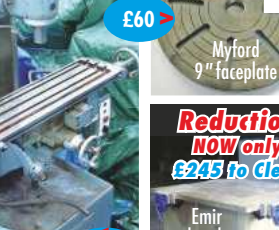
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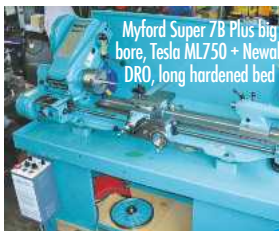
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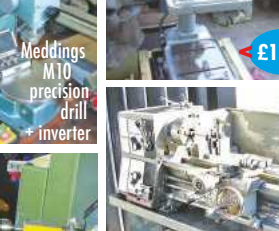
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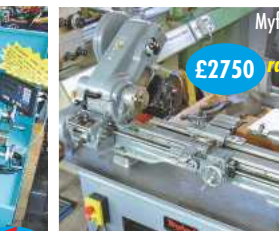
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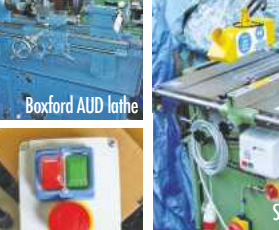
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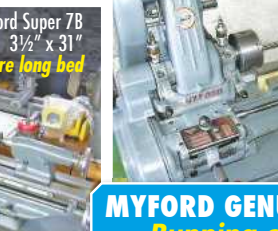
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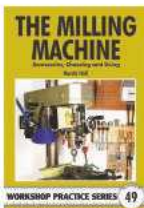
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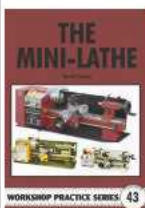
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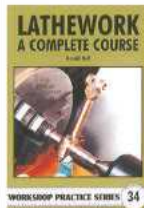
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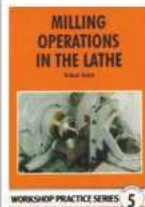
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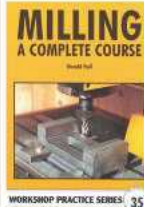
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